Nutrient Cycling in Rivers

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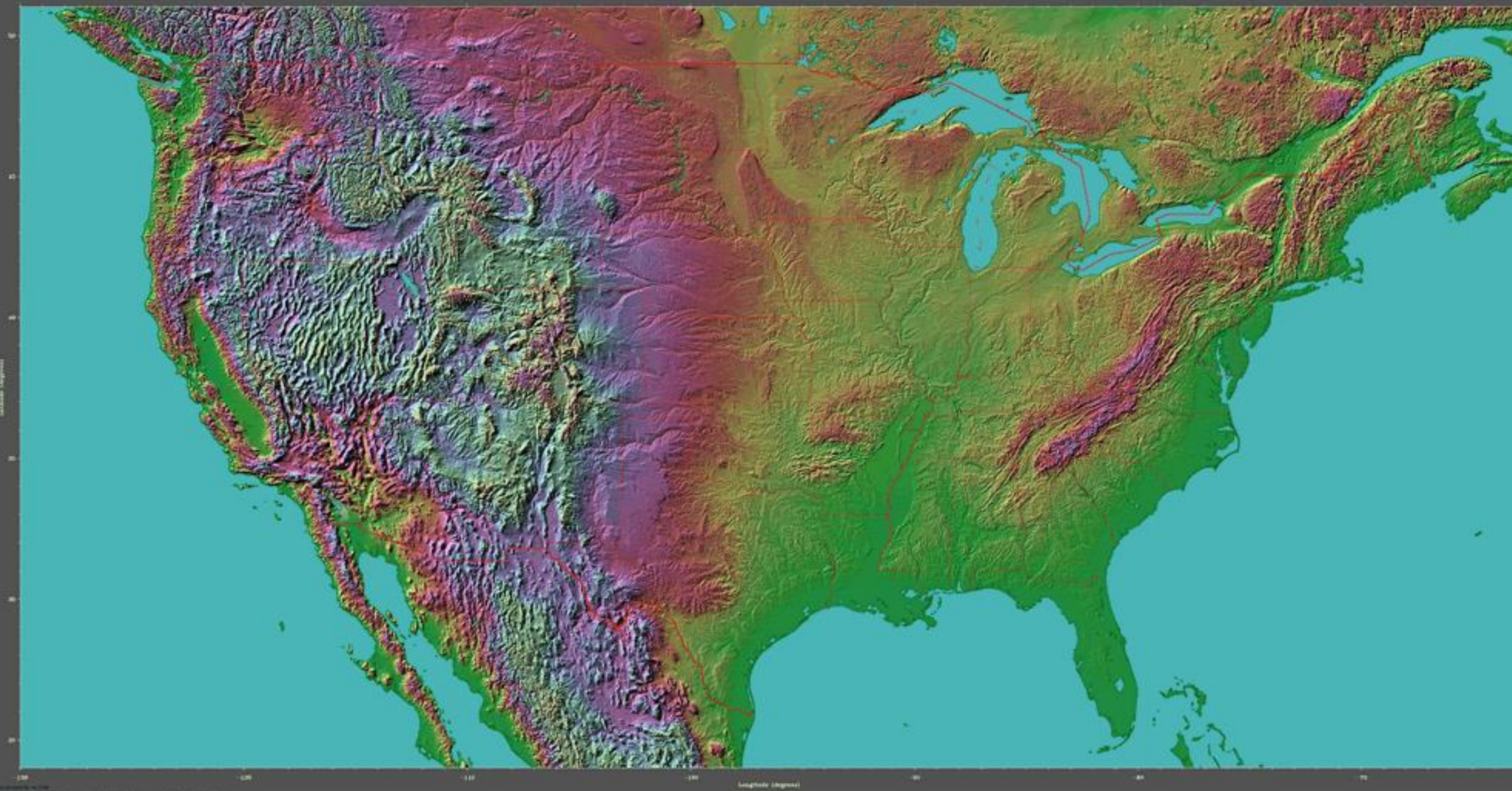
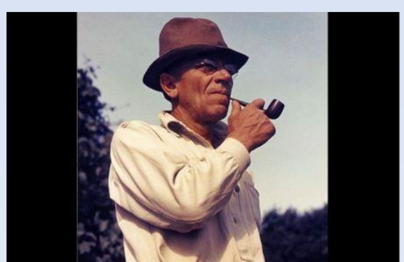


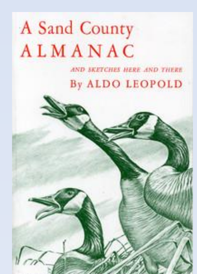
22.29°N 127.83°W

Nutrients in Rivers
Perspectives

Between each of his excursions through the biota, [Molecule] X lay in the soil and was carried by the rains, inch by inch, downhill… X rode down the spring freshet, losing more altitude each hour than heretofore in a century. He ended up in the silt of a backwater bayou, where he fed a crayfish, a coon, and then an Indian, who laid him down to his last sleep in a mound on the riverbank. One spring an oxbow caved the bank, and after one short week of freshet X lay again in his ancient prison, the sea.

– Aldo Leopold (1949), "Odyssey" *in* A Sand County Almanac

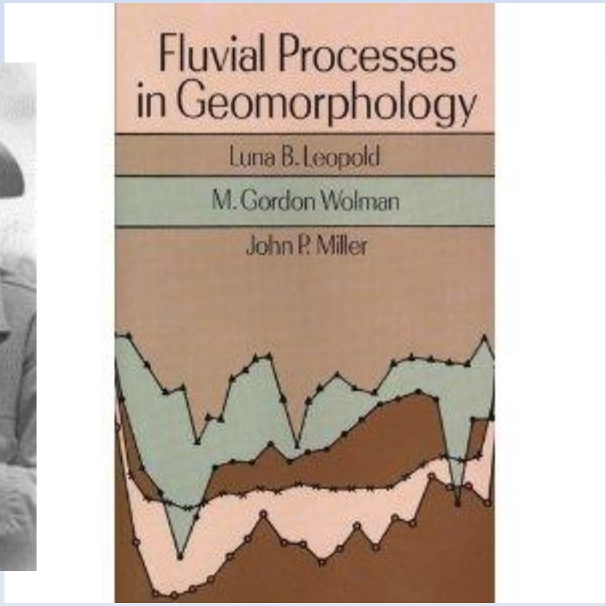




Nutrients in Rivers
Perspectives

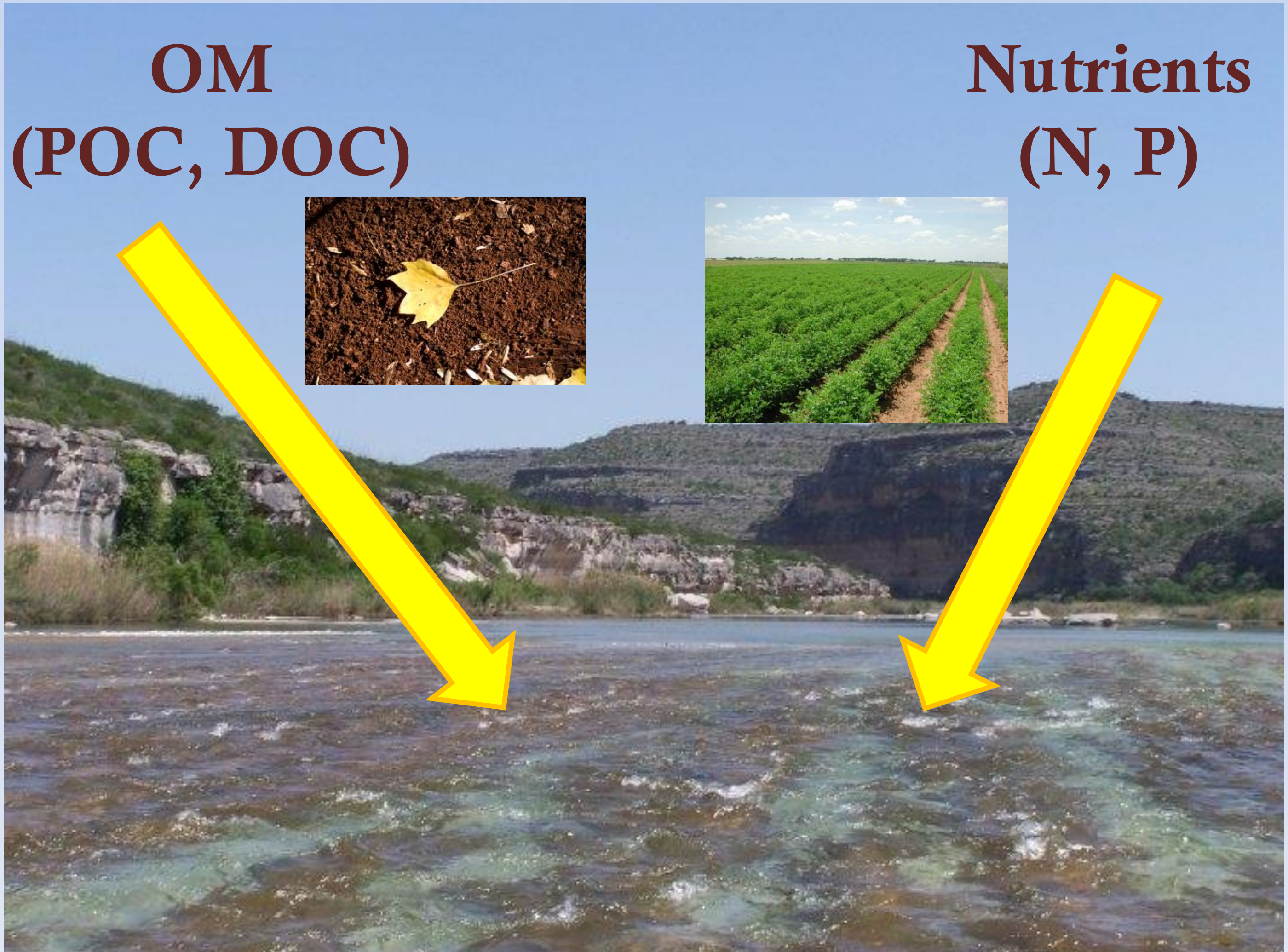
It has been said that streams are the gutters down which flow the ruins of continents.

– **Luna B. Leopold *et al*. (1964), *Fluvial Processes in Geomorphology***

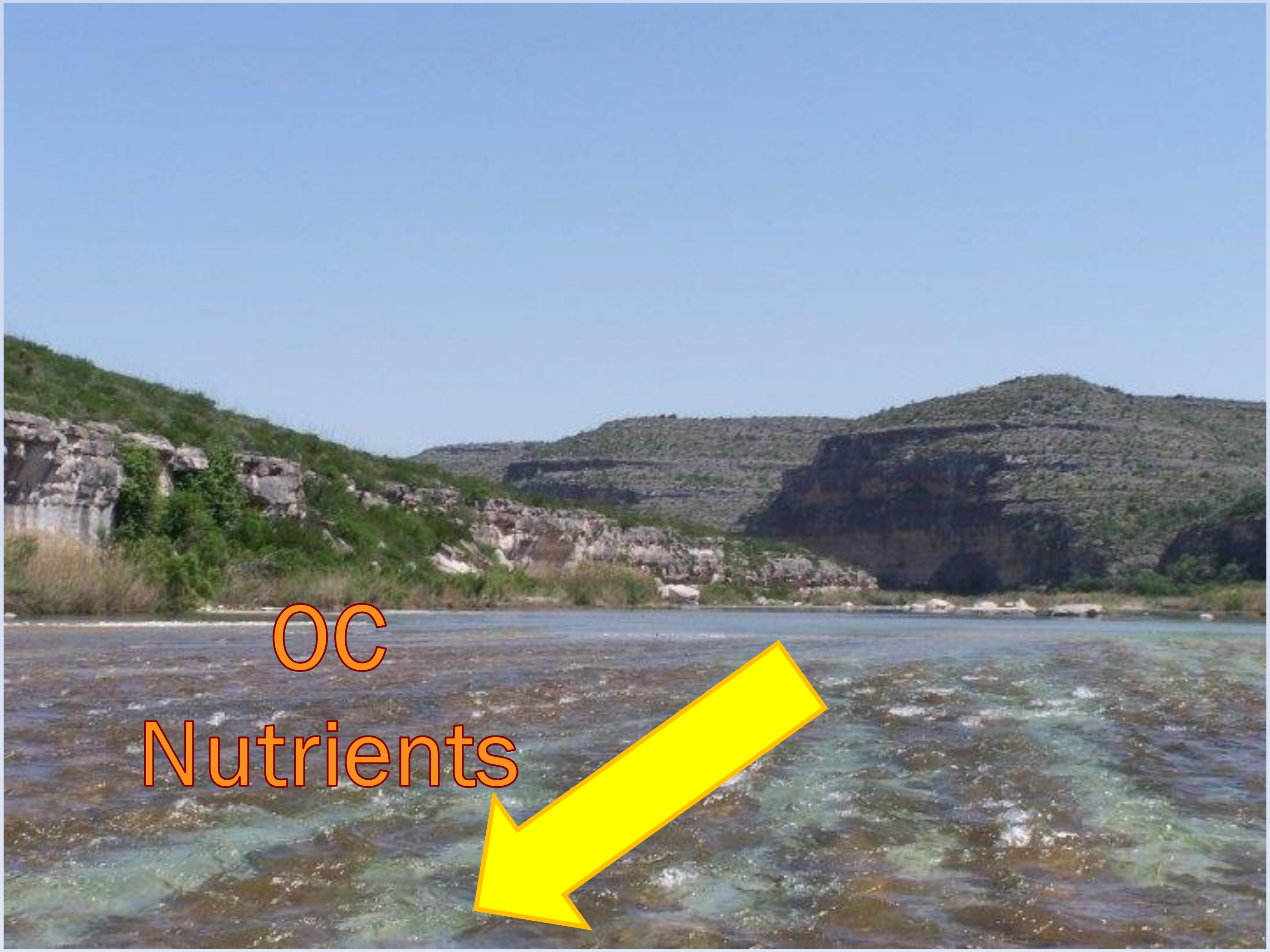


River Ecosystems

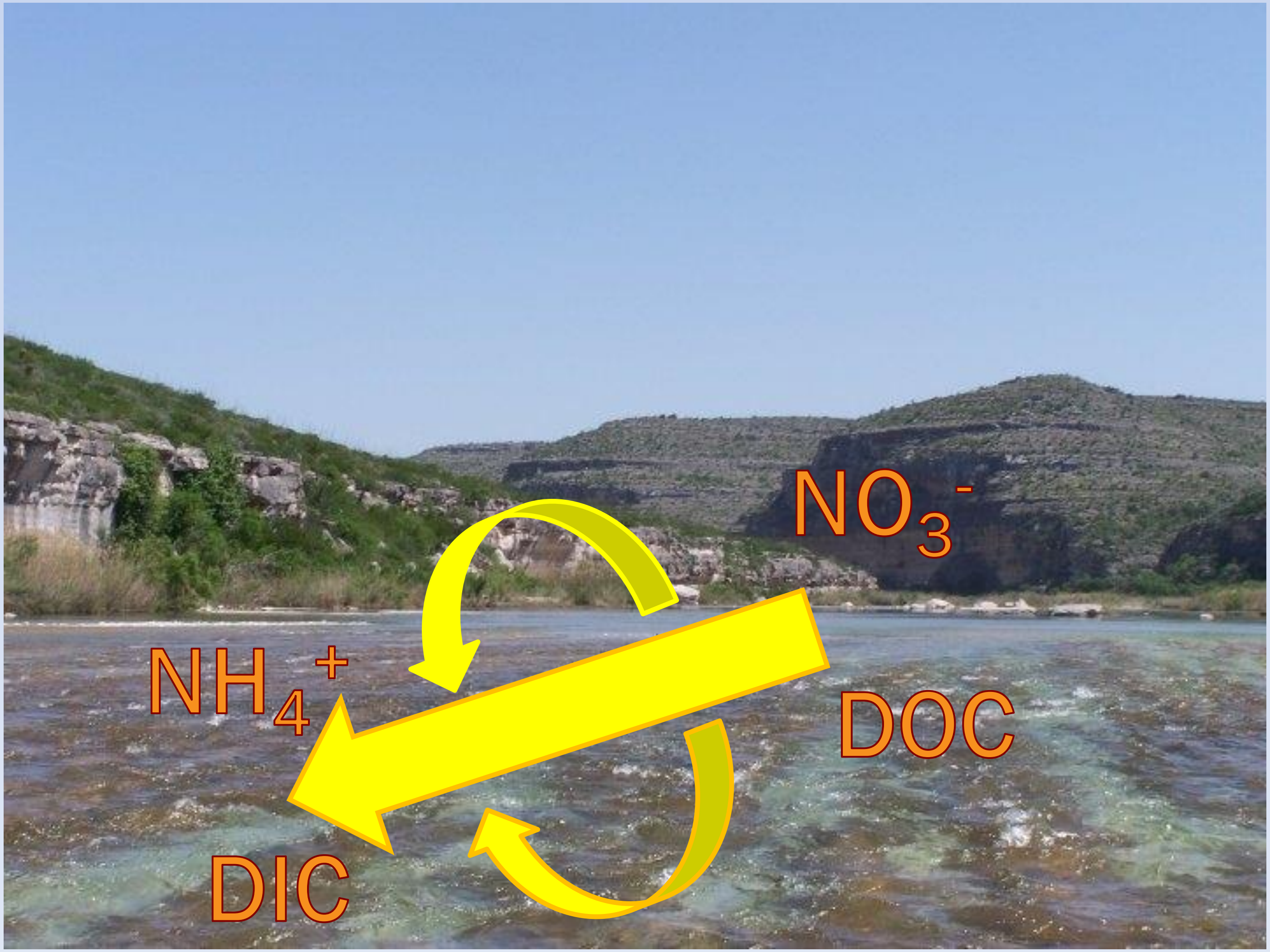
Recipients of Materials



Transport of Materials



Transport and Transformation



Outline for Today's Talk

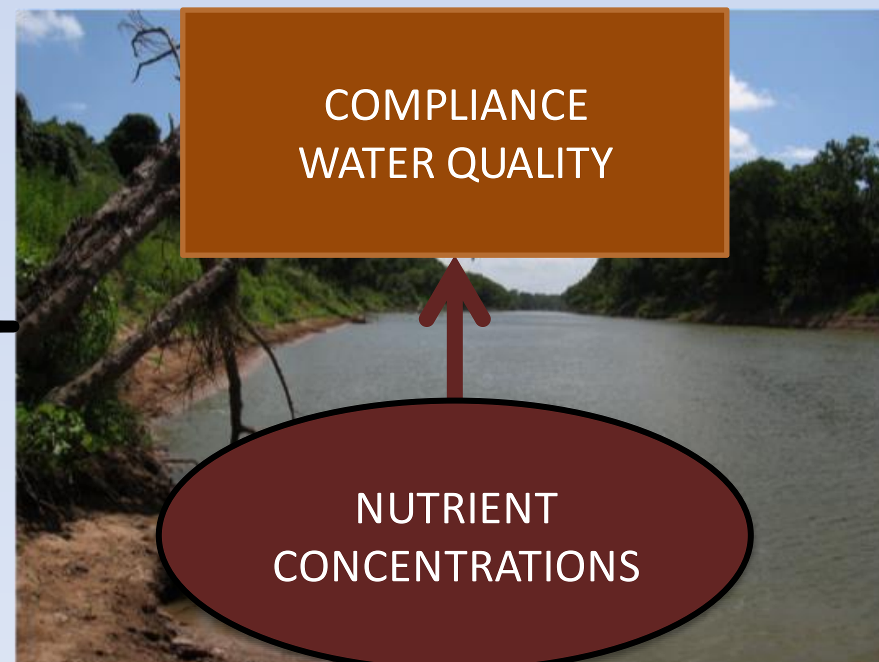
- Landscape controls of river nutrient concentrations
  - Brazos River

- Metabolism and organic carbon processing by bacteria in a river network
  - Rio Grande drainage

Landscape Controls of River Nutrient Concentrations

Sliva & Williams 2001; Alan 2004; Dodds & Oakes 2006, 2008

Landscape Controls of River Nutrient Concentrations



Sliva & Williams 2001; Alan 2004; Dodds & Oakes 2006, 2008

Landscape Controls of River Nutrient Concentrations

LULC

Urban
Rangeland
Forest
Agriculture

King et al. 2005; Dow et al. 2006

Landscape Controls of River Nutrient Concentrations

<u>LULC</u>

Urban
Rangeland
Forest
Agriculture

<u>Physiography</u>

Climate
Geology
Topography
Stream Order
Stream Density

King et al. 2005; Dow et al. 2006

Landscape Controls of River Nutrient Concentrations

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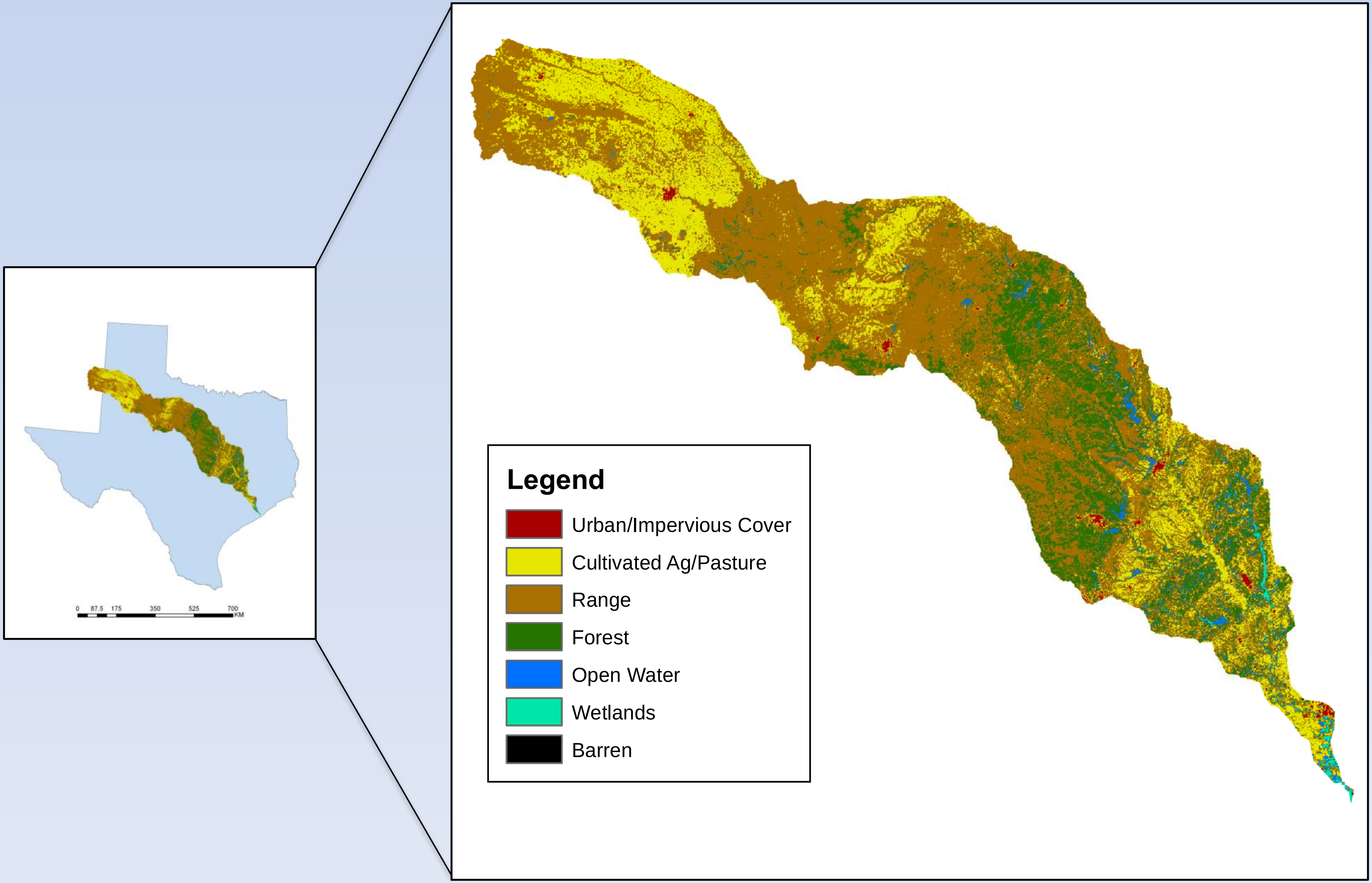
King et al. 2005; Dow et al. 2006

Research Questions

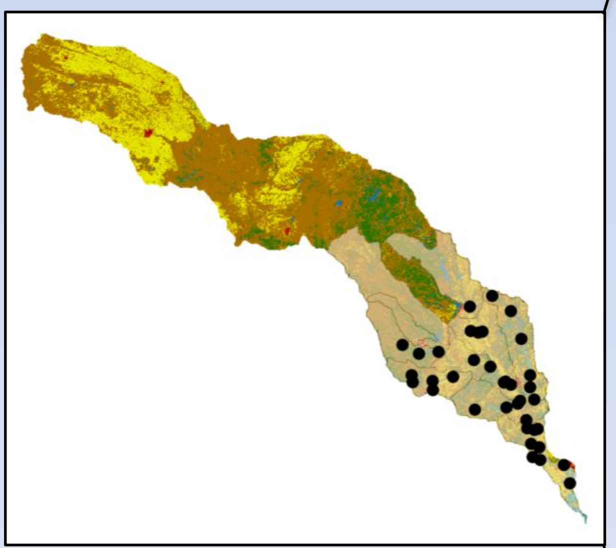
- What effect do land-use and physiographic gradients have on nutrient concentrations across a large river network?

- What are the individual and combined influences of these factors on river nutrient dynamics?

Brazos River, TX



Brazos River, TX



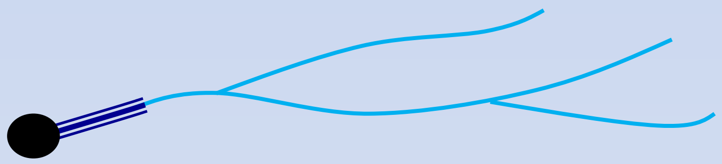
~41,000 km^2
6 sub-basins
33 sites

Methods

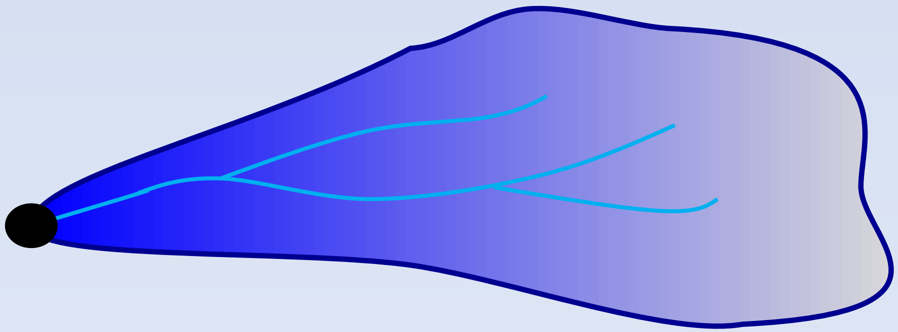
- Water collected over 3 seasons (2008 – 2009)
- Environmental parameters
- Nutrients
  - Total and dissolved N and P
  - Particulates (NVSS, C, N, P)
  - POC and DOC
  - Chl *a*
- GIS

LULC Scales Used

Local buffer (100m buffer, 2km upstream)



Catchment



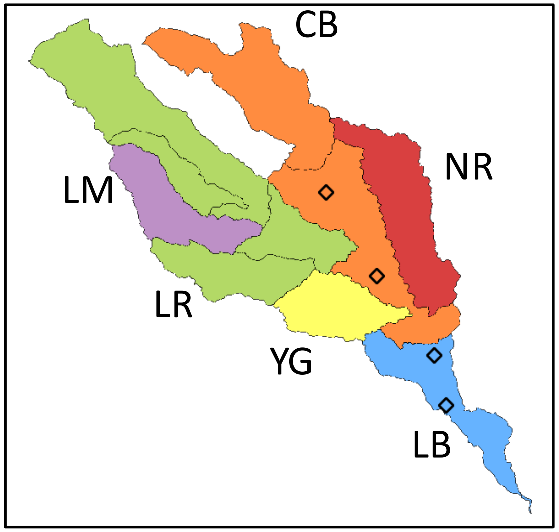
Data Analysis

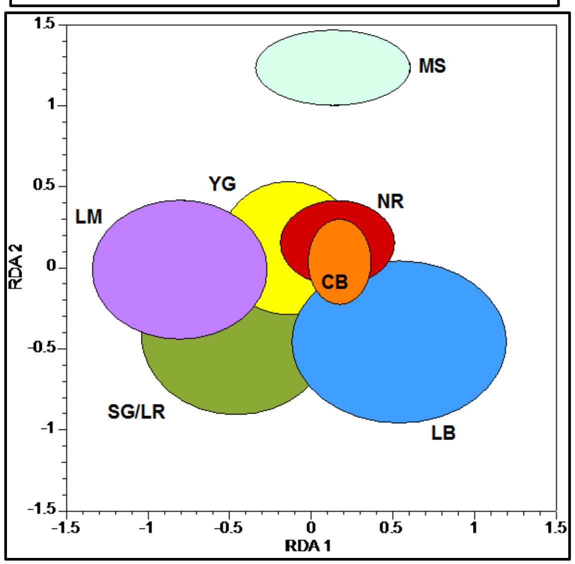
- Used a multivariate analytical framework
- Redundancy Analysis (RDA)
  - Relationships between LULC and Physiographic predictors and in-stream nutrient concentrations
  - Can express gradients across the watersheds as combinations of variables
- Variance Partitioning
  - Evaluate the independent and combined effects of the two predictor sets on nutrient concentrations
  - LULC versus Physiographic

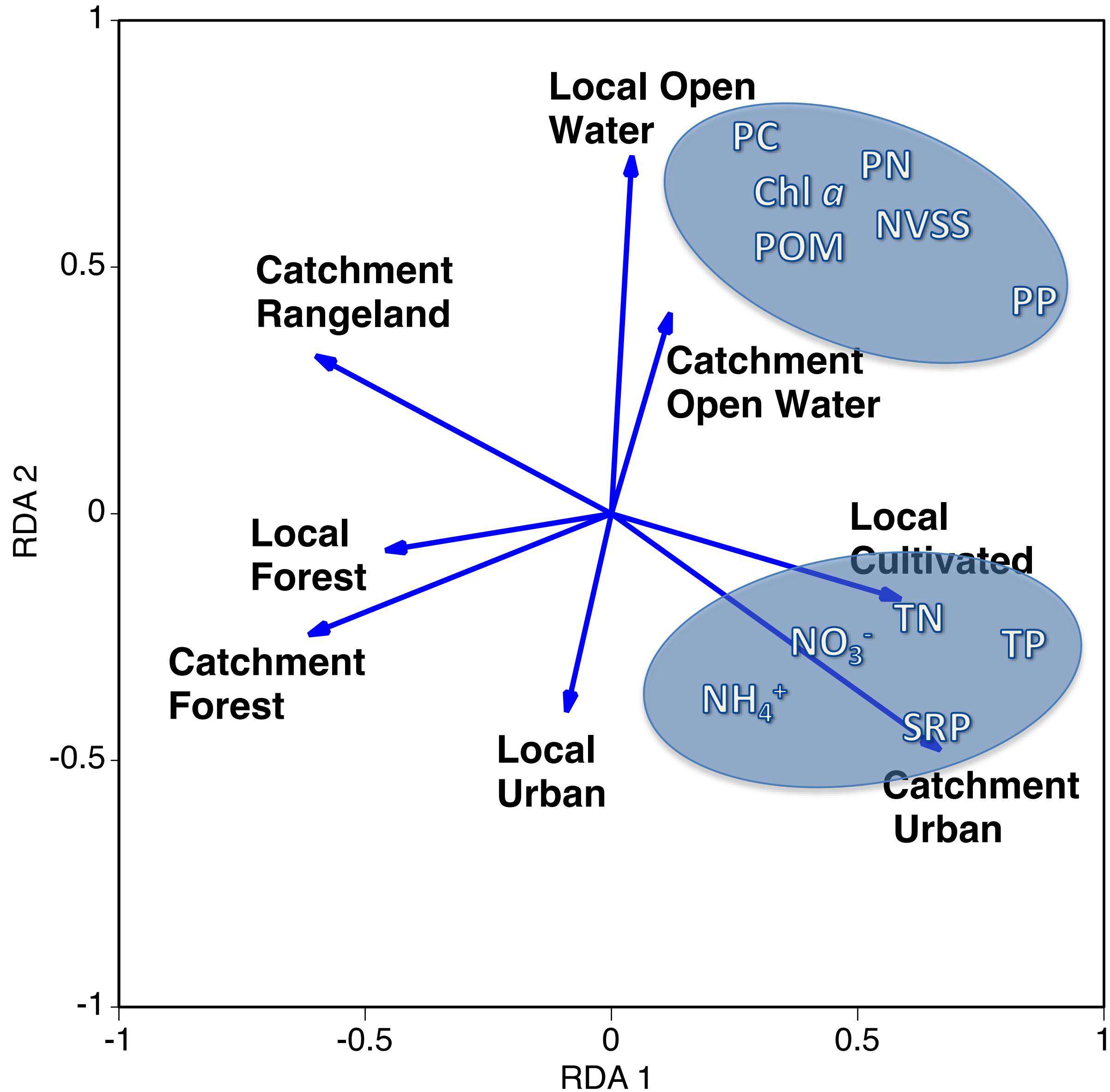
Predictor Variables

- **Land Use/Land Cover**
  - Urban
  - Cultivated Agriculture
  - Rangeland
  - Forest
  - Open Water
  - Wetlands
- **Physiographic variables**
  - Longitude [Rainfall]
  - Catchment Area
  - Stream Density
  - Ecoregion (Level-III)
  - Mean Slope
  - Max Slope

LULC Predictors



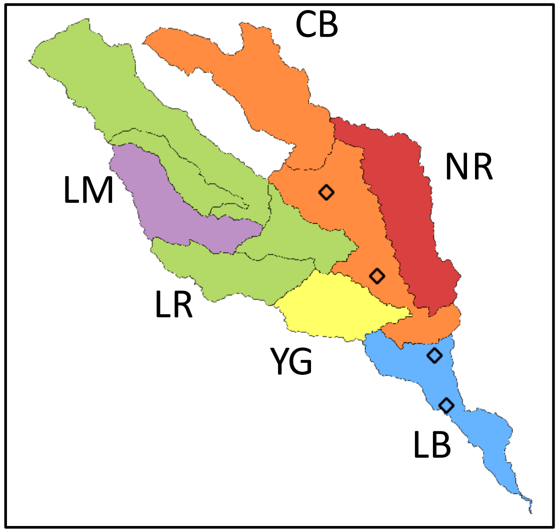


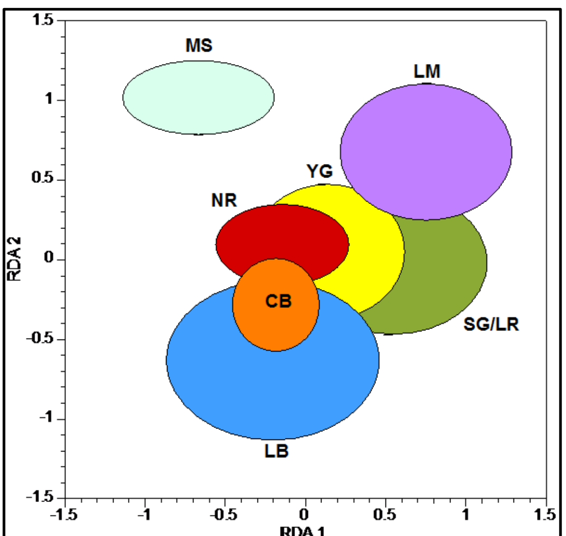


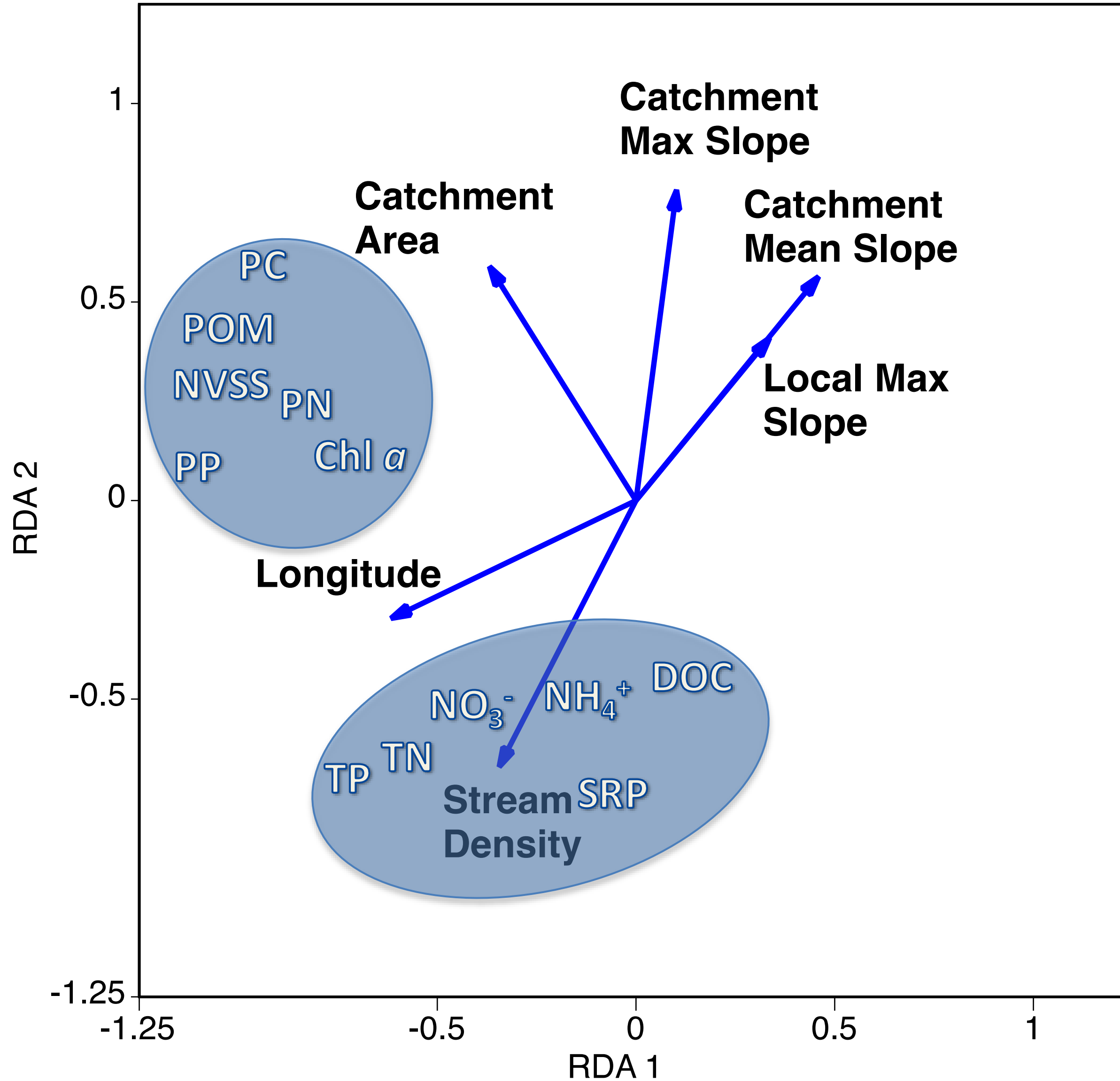
Adjusted $R^2 = 0.26$

Becker et al. 2014. *Freshwater Science.*

Physiographic Predictors



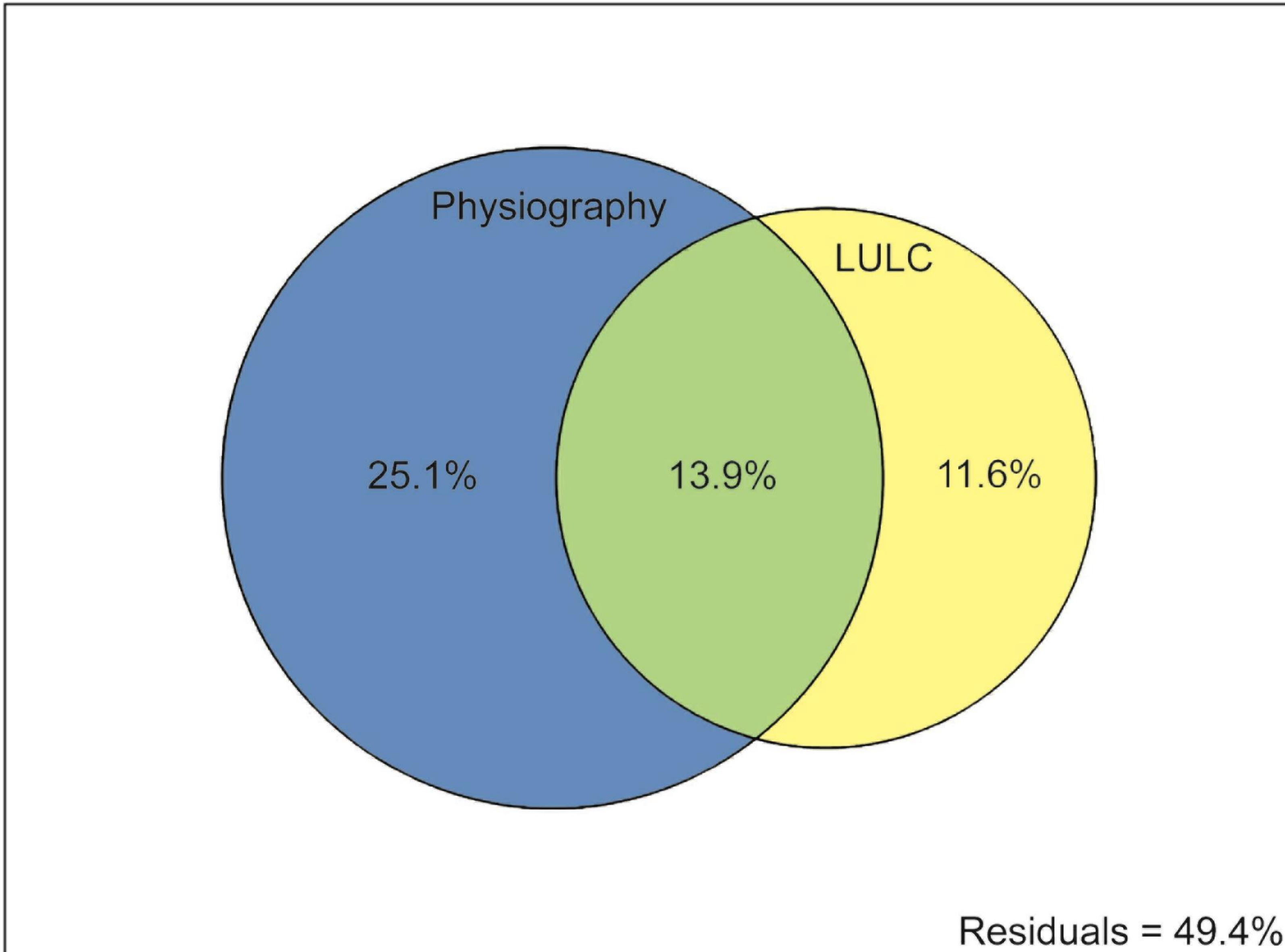




Adjusted $R^2 = 0.39$

Becker et al. 2014. *Freshwater Science.*

Variance Partitioning



What Does This Mean?

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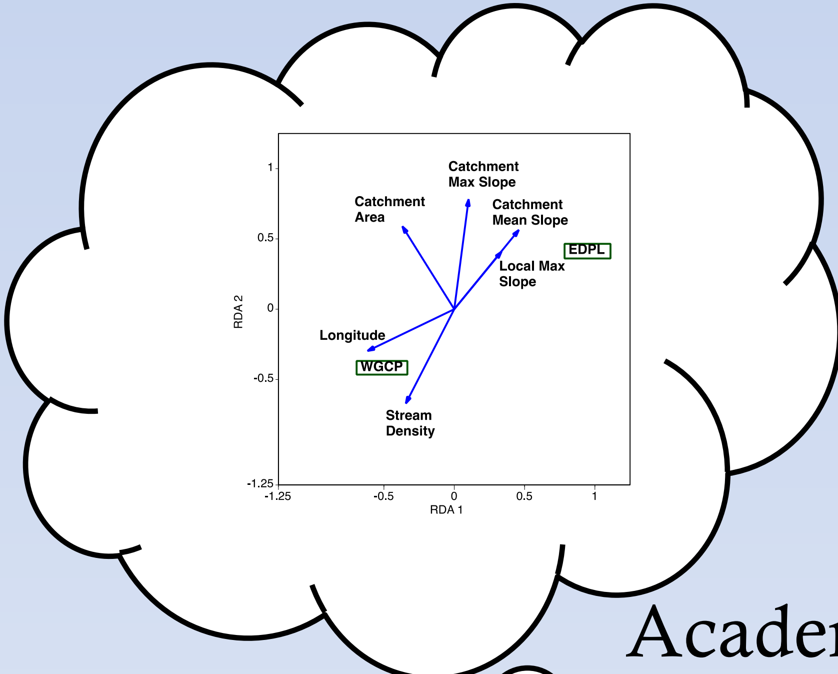
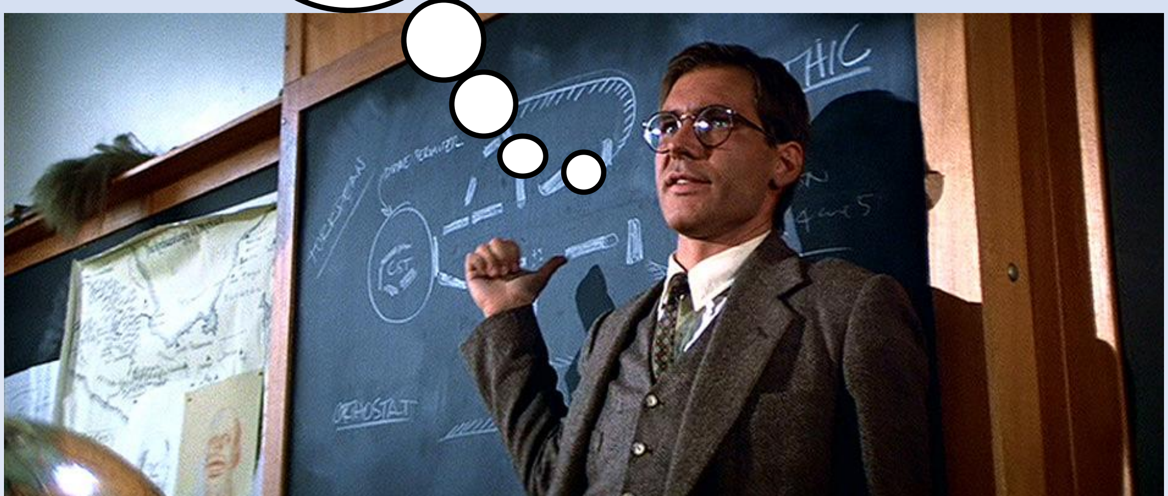


Academic Scientist



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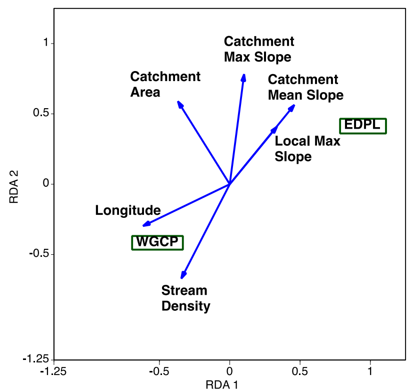

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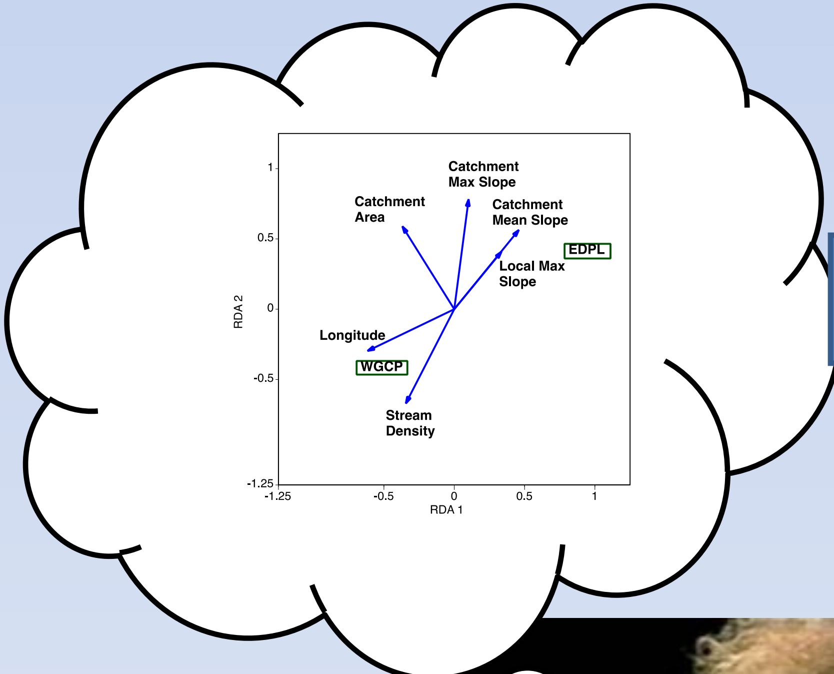


Relevance for Resource Managers?

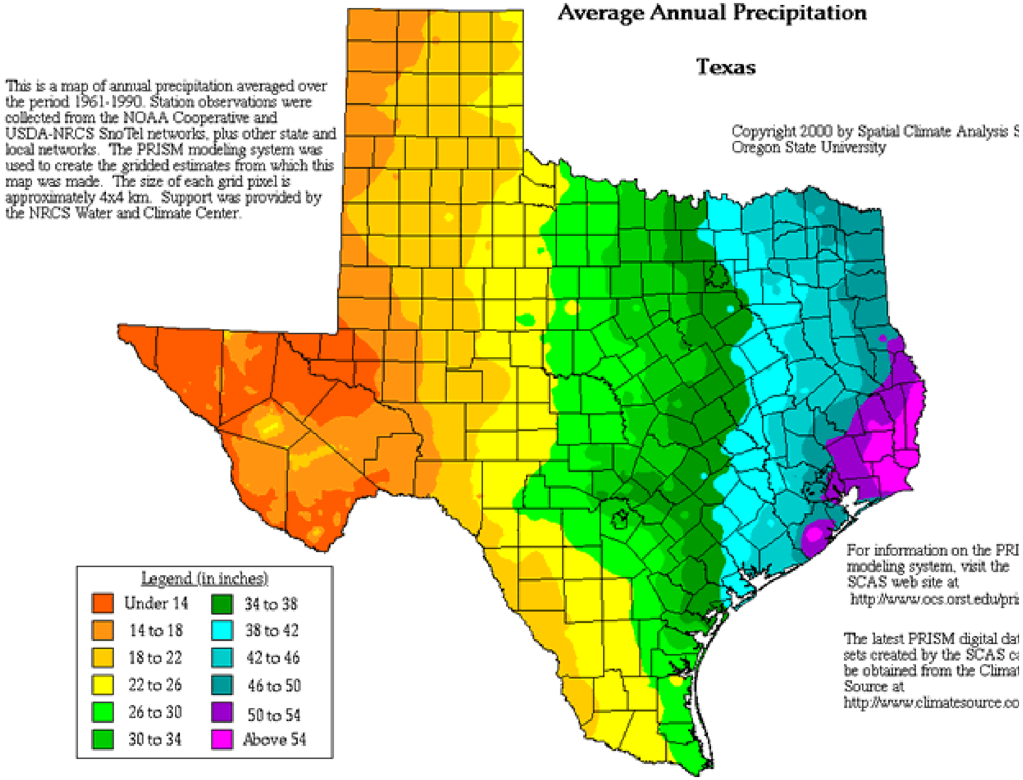
Academic Scientist

What Does This Mean?

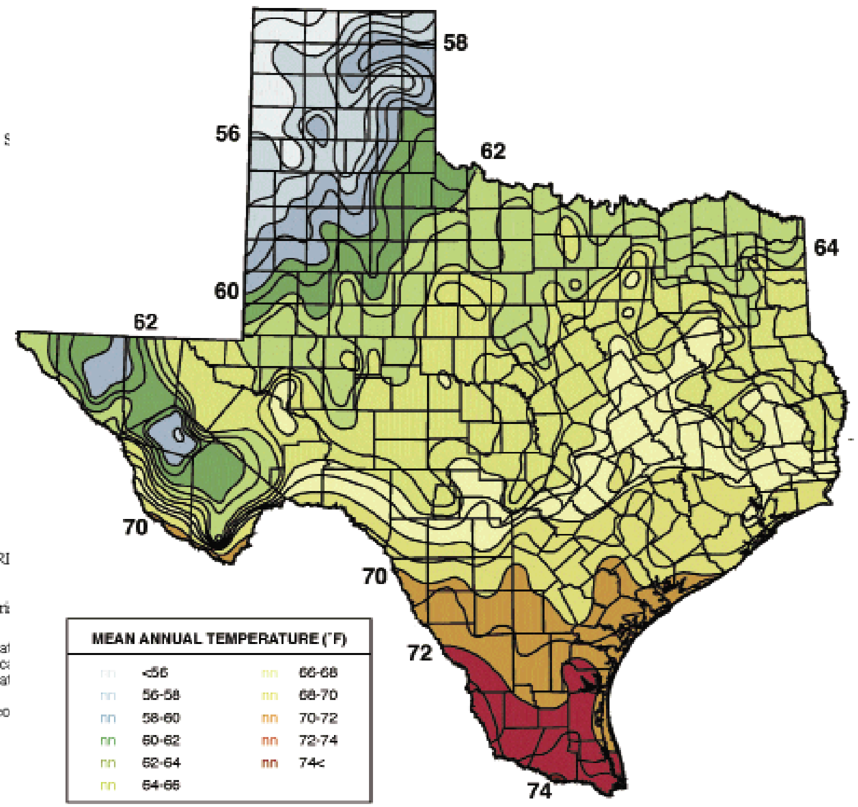
- Physiography (geology, landscape setting, climate) set the "baseline" for nutrients
  - LULC was also important, but to a lesser extent
- Especially relevant for large drainages that cross environmental gradients
  - Multiple ecoregions
- Setting water quality criteria?
  - Ecoregion or drainage-based *vs* state-wide
  - Implications for identification of reference systems

Major Gradients in Texas

Annual Precipitation



Annual Temperature



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- Setting <u>water quality criteria</u>?
  - State-wide *vs* Ecoregion or drainage-based
  - Implications for identification of <u>reference systems</u>

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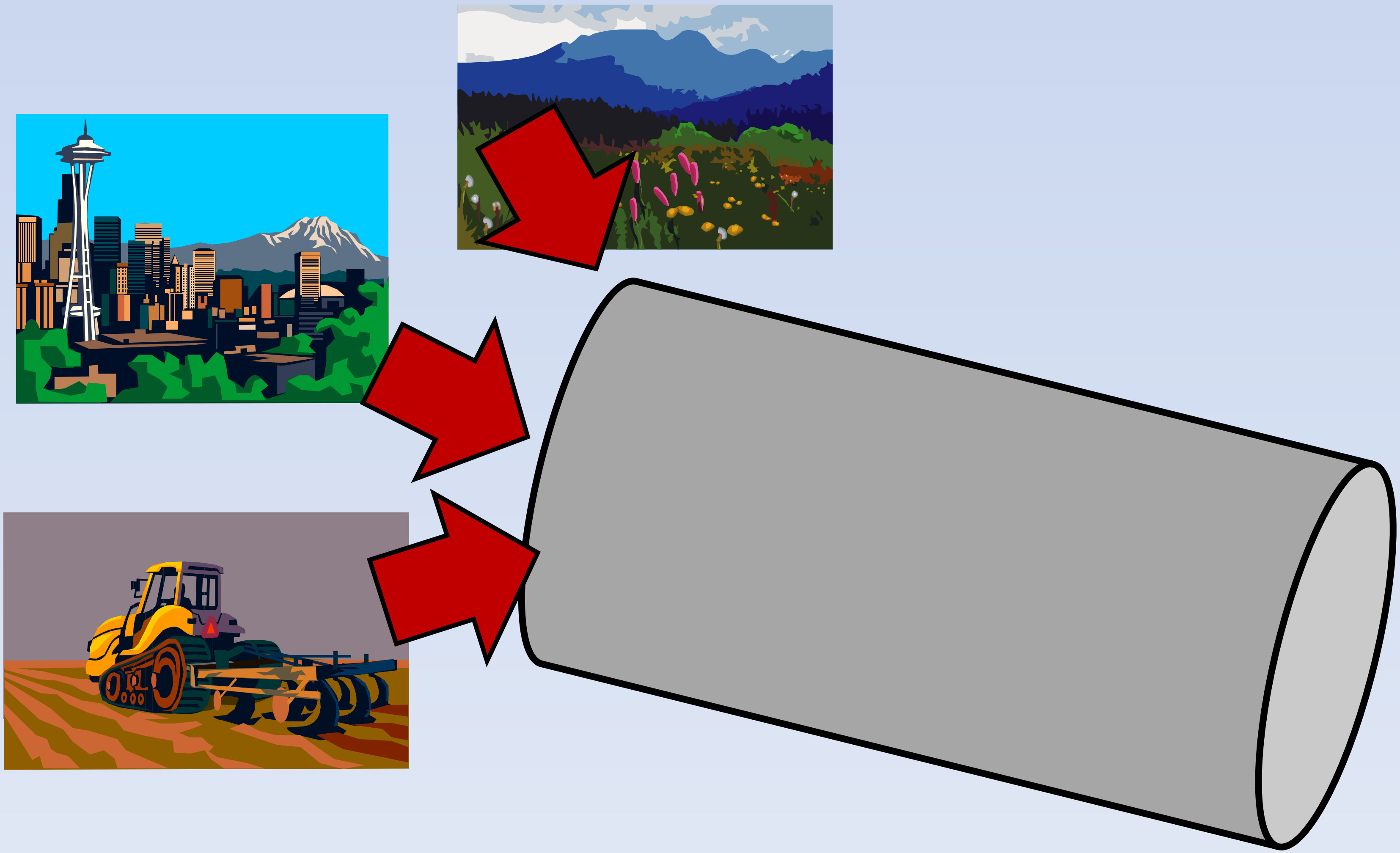
Inland Waters as "Reactive Pipes" in a Landscape



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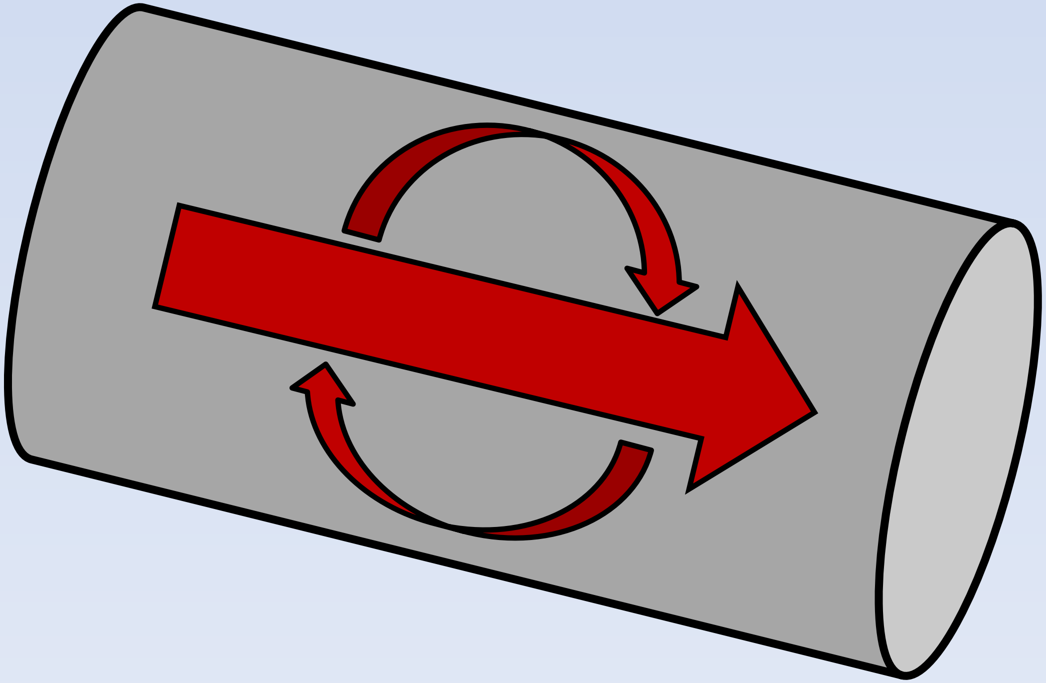

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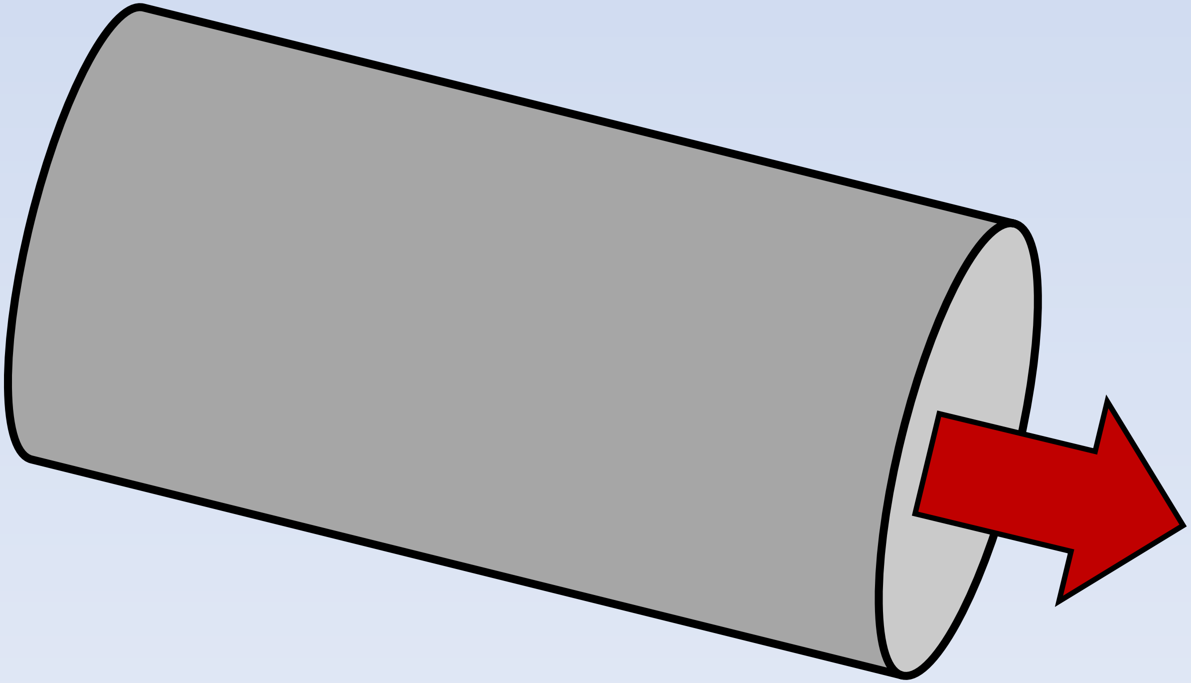
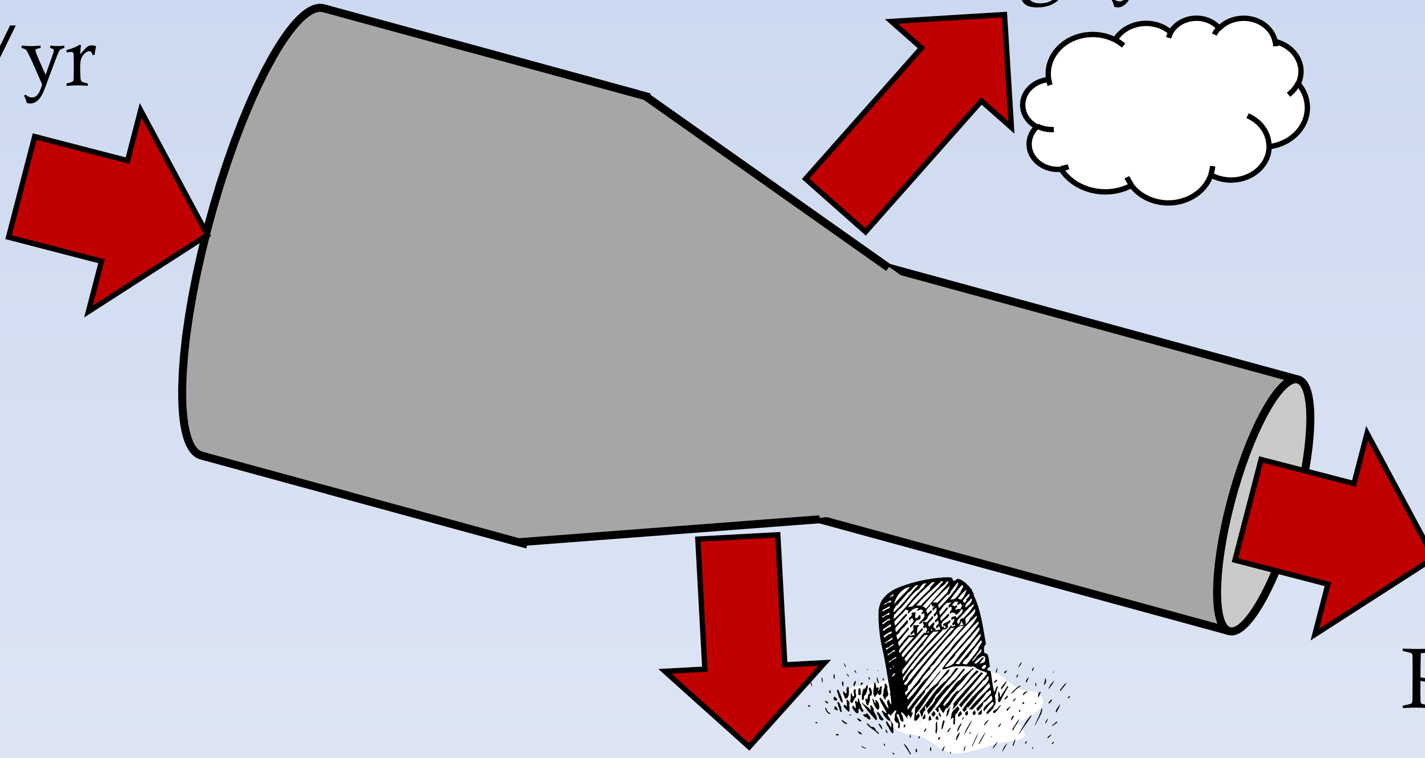
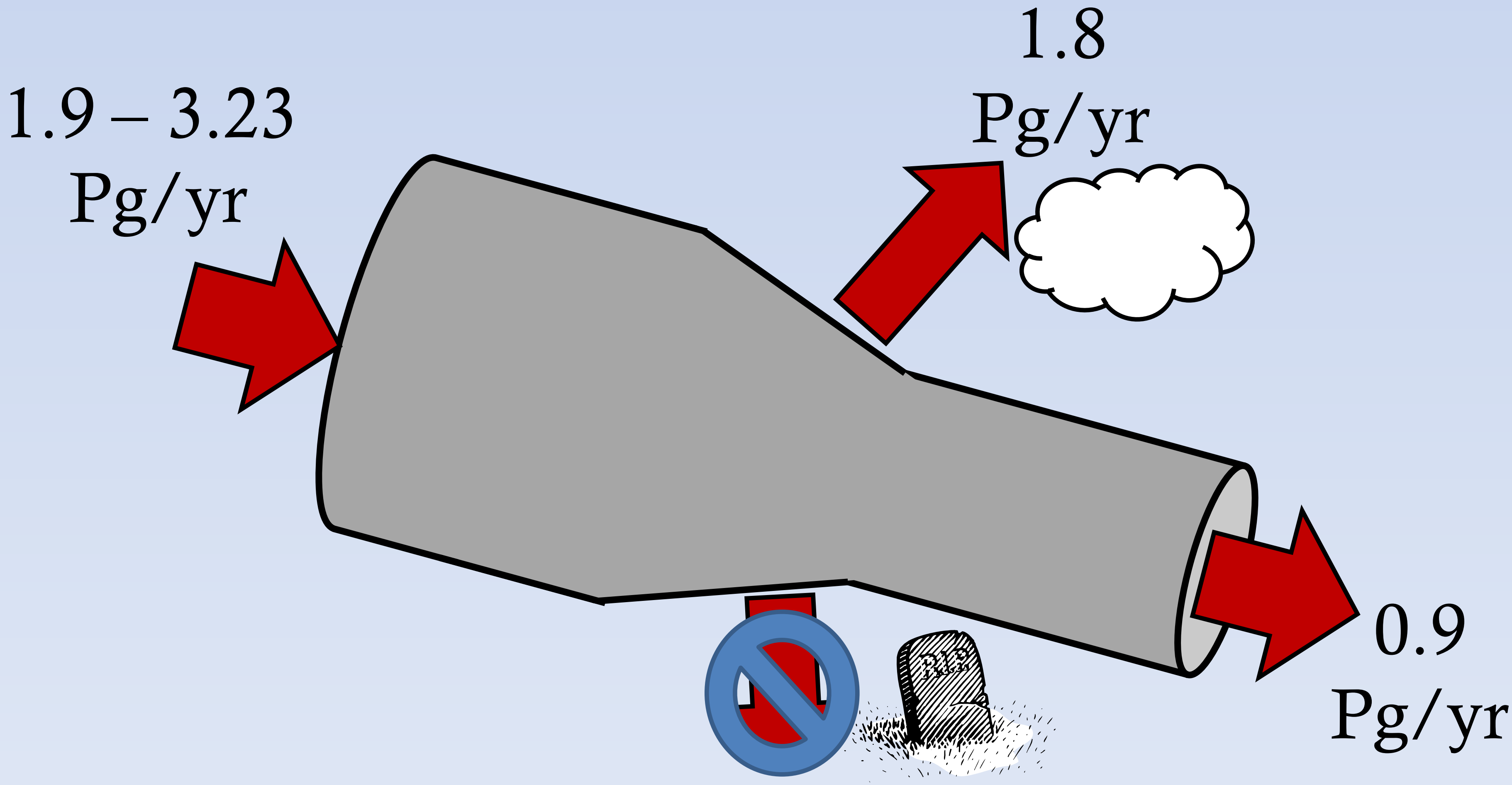


Inland Waters and Global Carbon Cycling



Raymond et al. 2013; Cole et al. (2007)

Rivers and Global Carbon Cycling



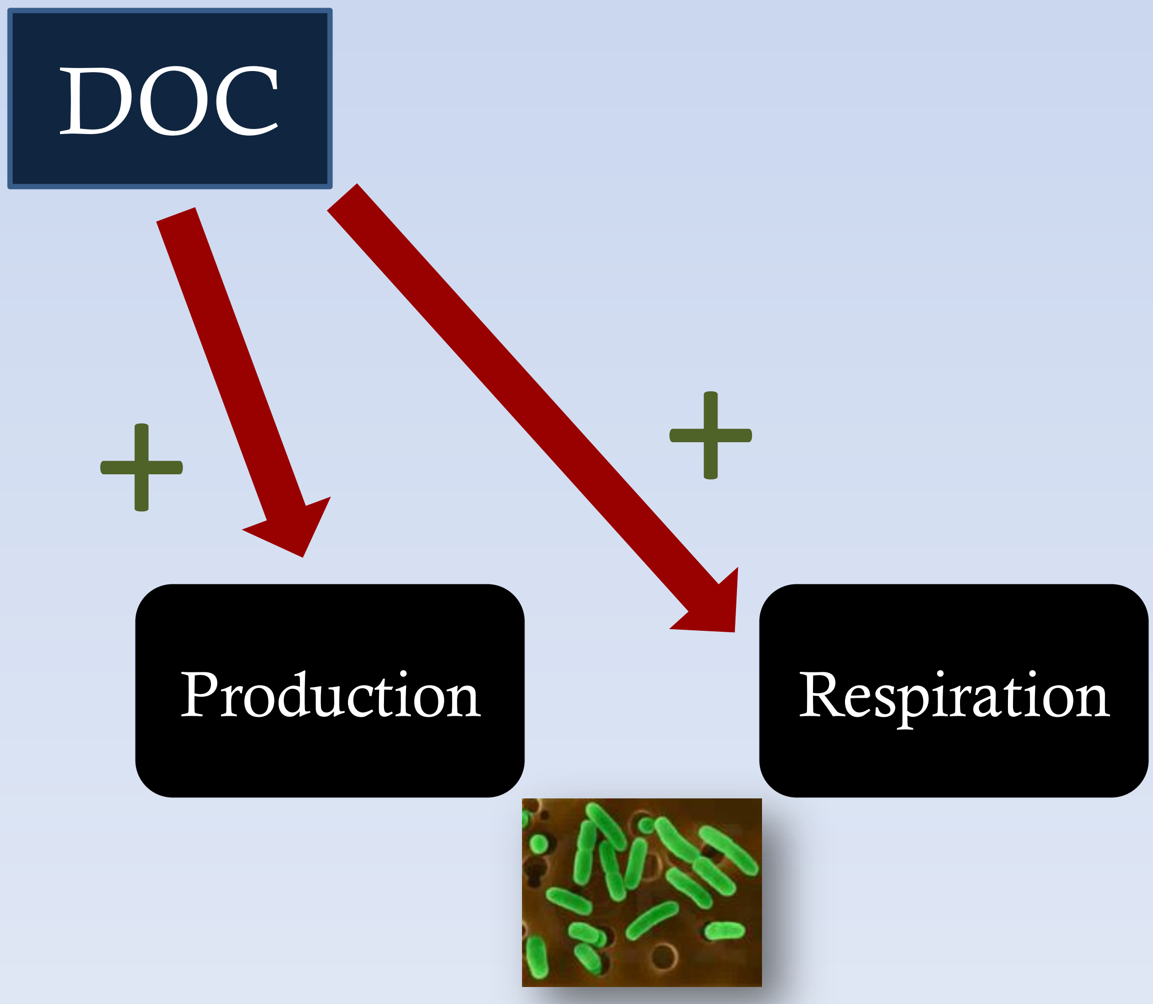
Raymond et al. 2013; Cole et al. (2007)

Bacterial C Metabolism in Rivers

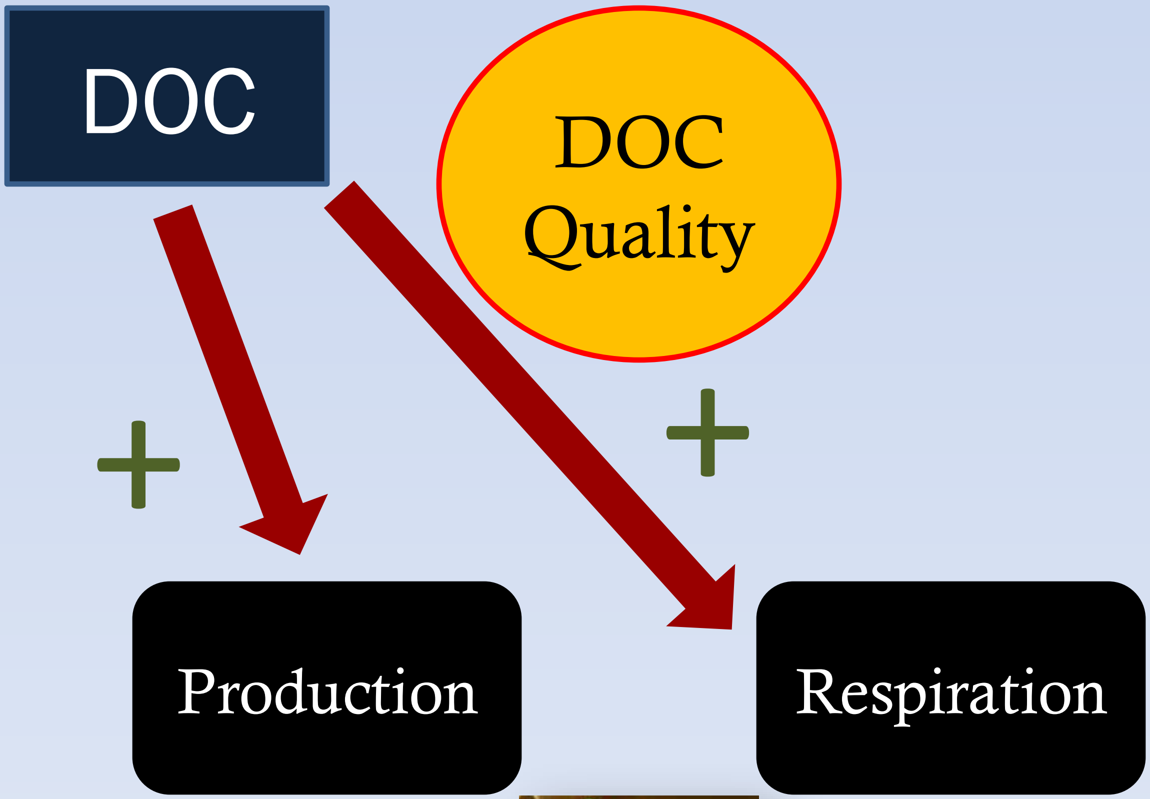
Production

Respiration

Bacterial C Metabolism in Rivers



Bacterial C Metabolism in Rivers



Bacteria and Organic Carbon

- All OC is not the same
  - Labile *vs* refractory

- Series of pools varying in decomposition rates
- Autochthonous more labile than allochthonous

(Sondergaard and Middelboe 1995, del Giorgio and Davis 2002, Ostapenia et al 2009)

Bacterial C Metabolism in Rivers

DOC

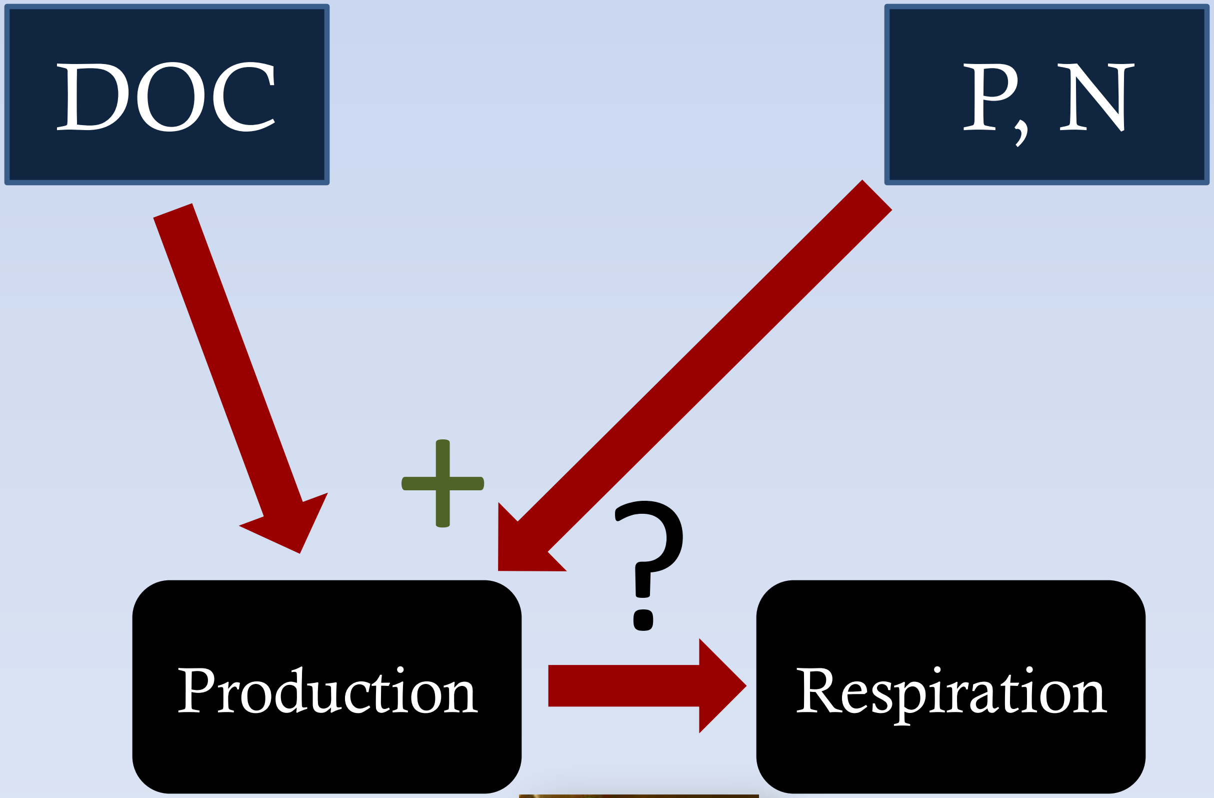
P, N

+

Production

Respiration

Bacterial C Metabolism in Rivers

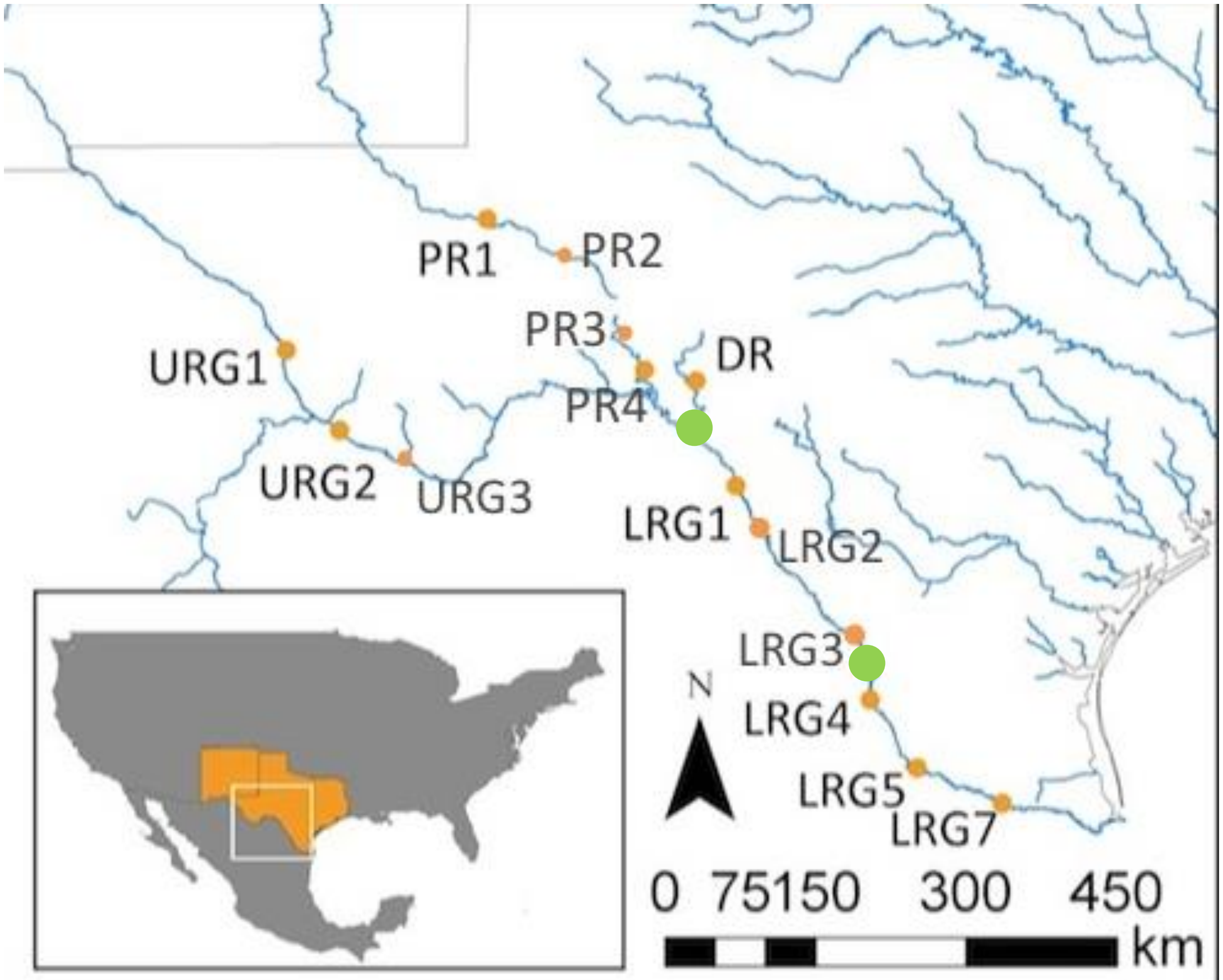


Questions to Consider

- How does bacterial metabolism respond to environmental gradients in a complex riverine network?

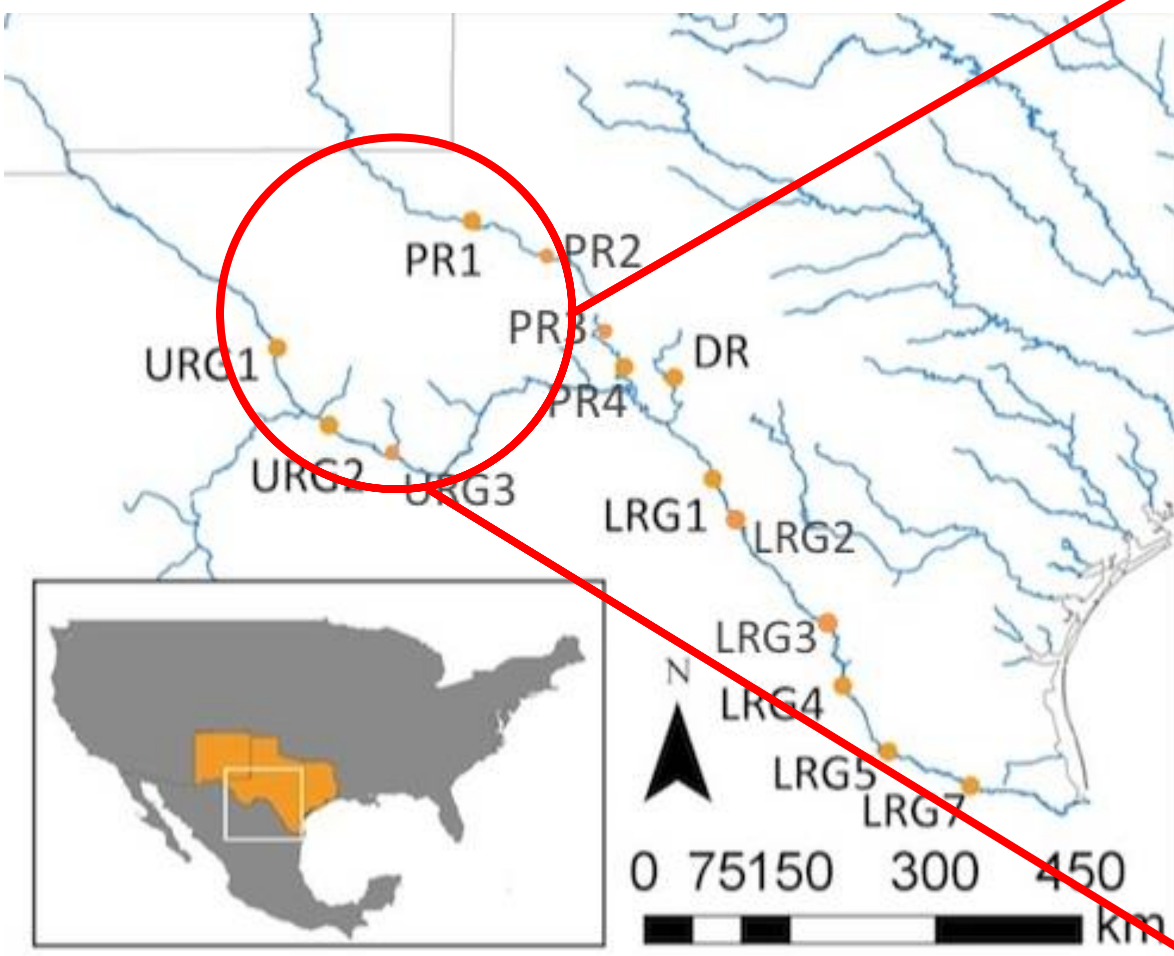
- What is the relative importance of physicochemical factors (e.g., inorganic nutrients) versus factors related to C quantity/quantity in determining bacterial C metabolism?

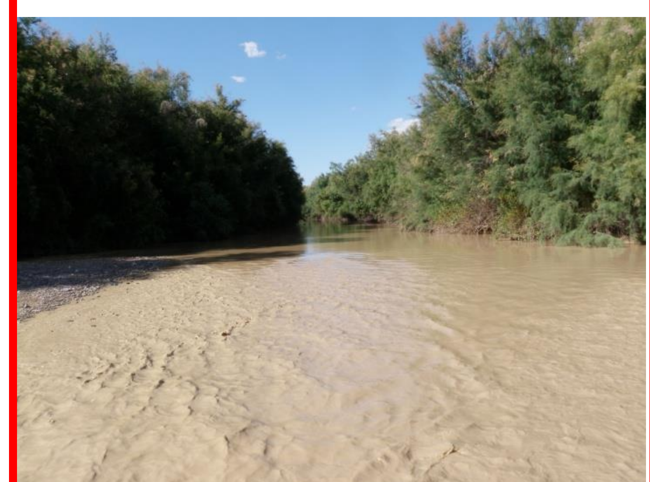
Lower Rio Grande/Rio Bravo del Norte



- Biogeoclimatic gradient
  - NW to SE
- Highly impacted
  - Hydrology
  - Reservoirs
- Large scale gradient in physicochemical conditions

Study Sites and Methods





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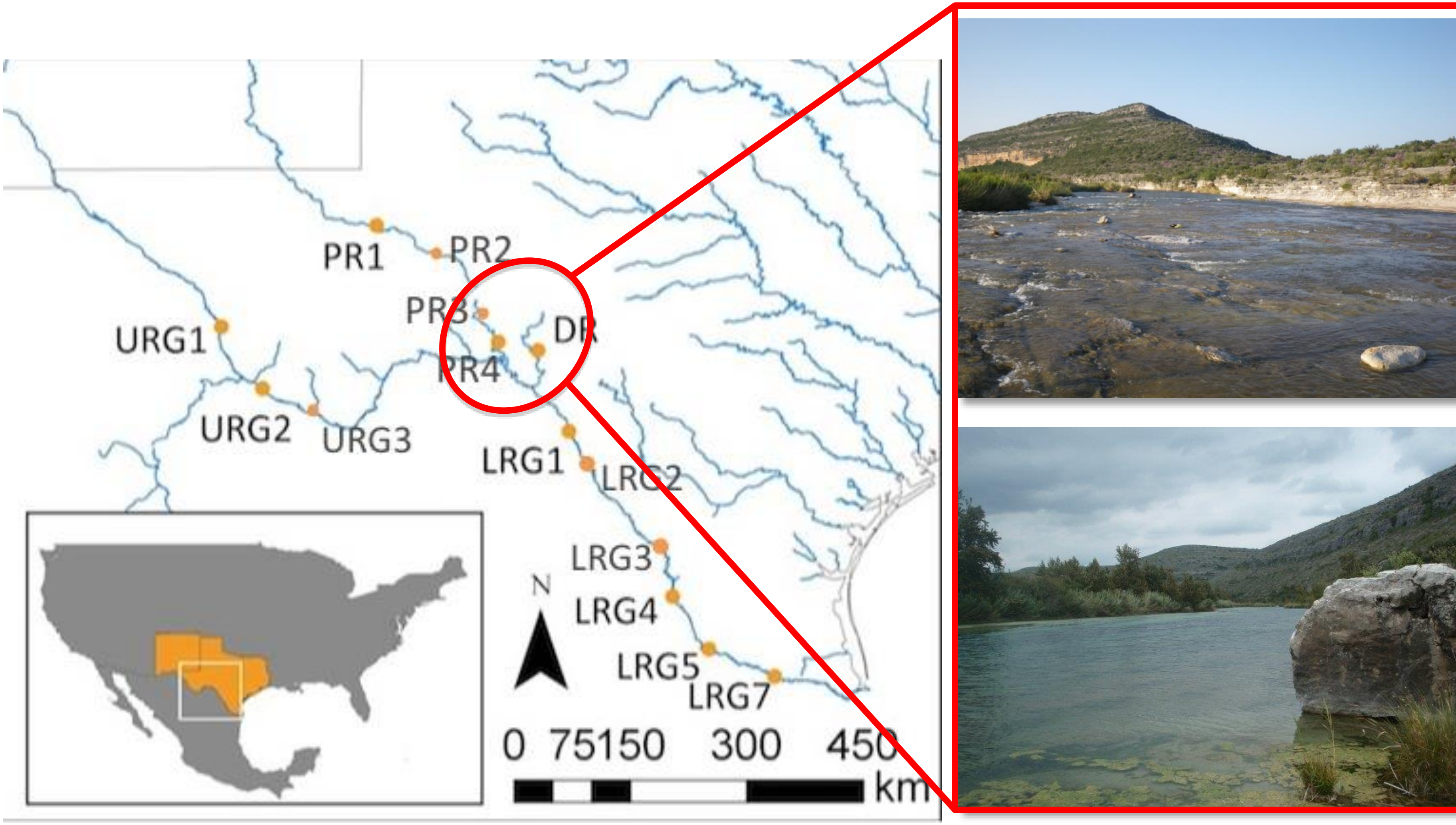

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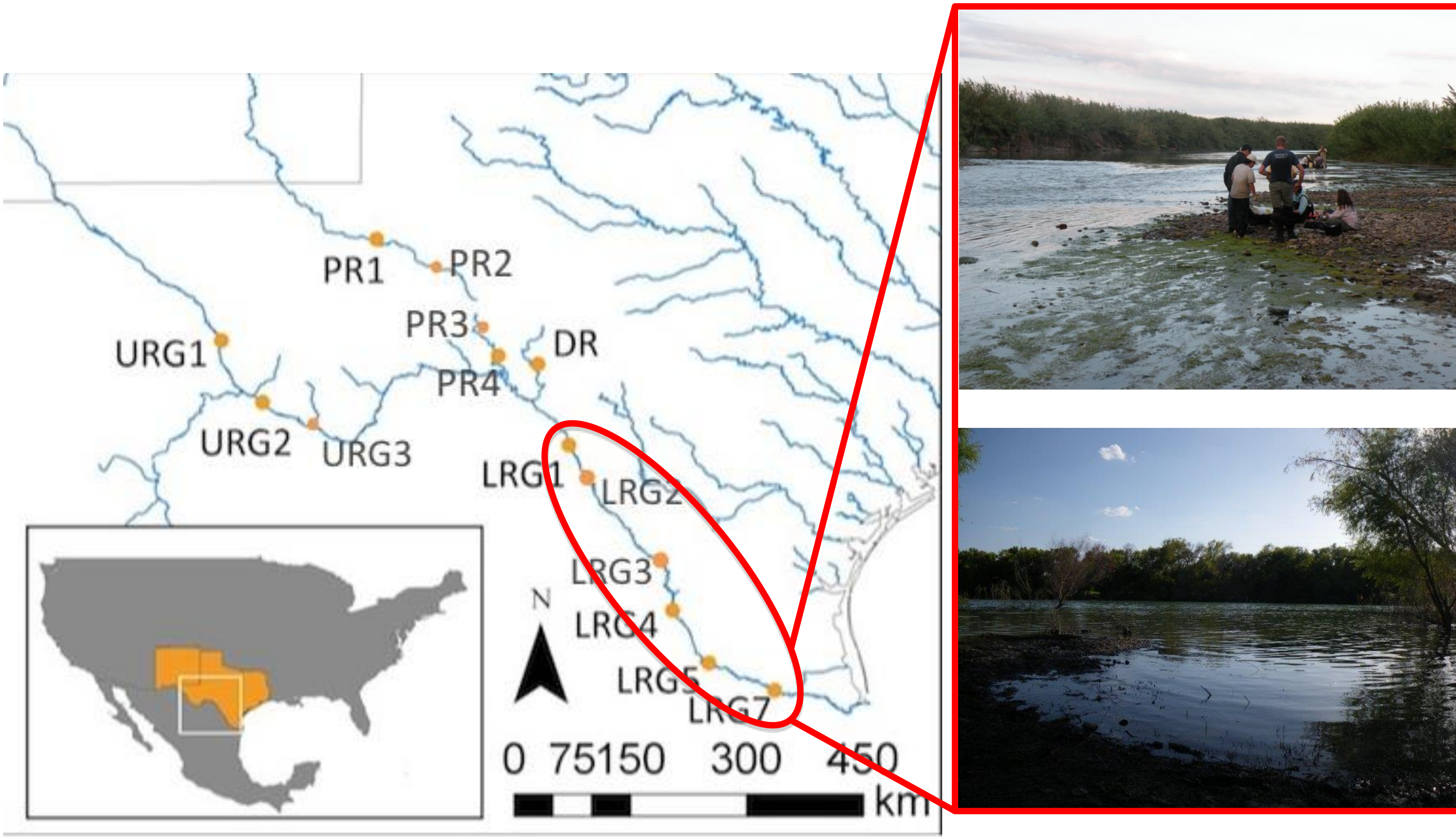
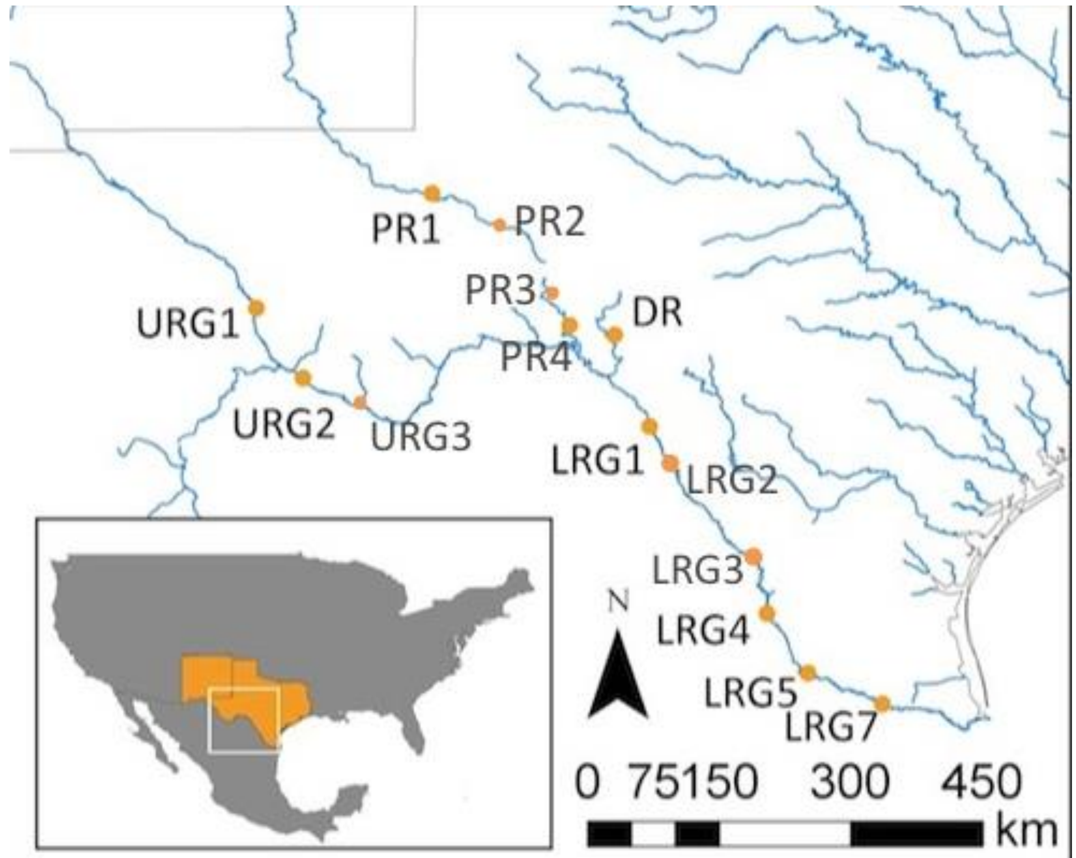


Study Sites and Methods

- 14 sites sampled
- Before, during, and after agricultural growing season (2010)
- Nutrient and water quality data
- BP and BR
  - ^{3}H-leucine BP and 2-d BOD incubations
- DOC, Abs_{440}, OC lability



Organic Carbon Lability

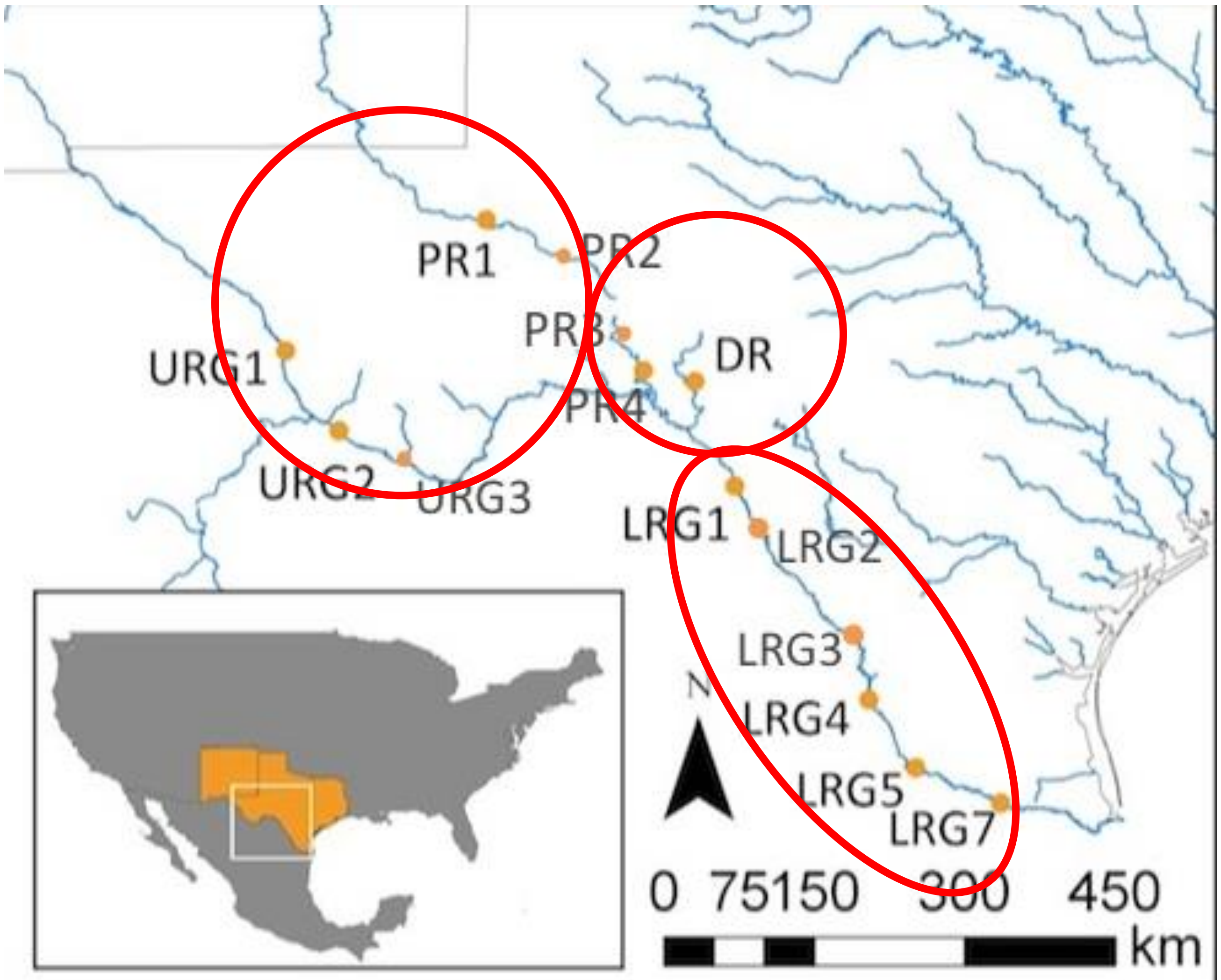
- Long-term BOD incubations
- First-order decomposition kinetics
- $BOD_t = BOD_{ult}(1\text{-}e^{-kt})$
- <1 µm water
- Day 2, 4, 8, 16, 20
- BOD_{ult} O_2 converted to C by multiplying by 0.3
- Solve for concentration of OC_L and *k*

Leonov 1974, Ostapenia et al 2009

Data Analysis

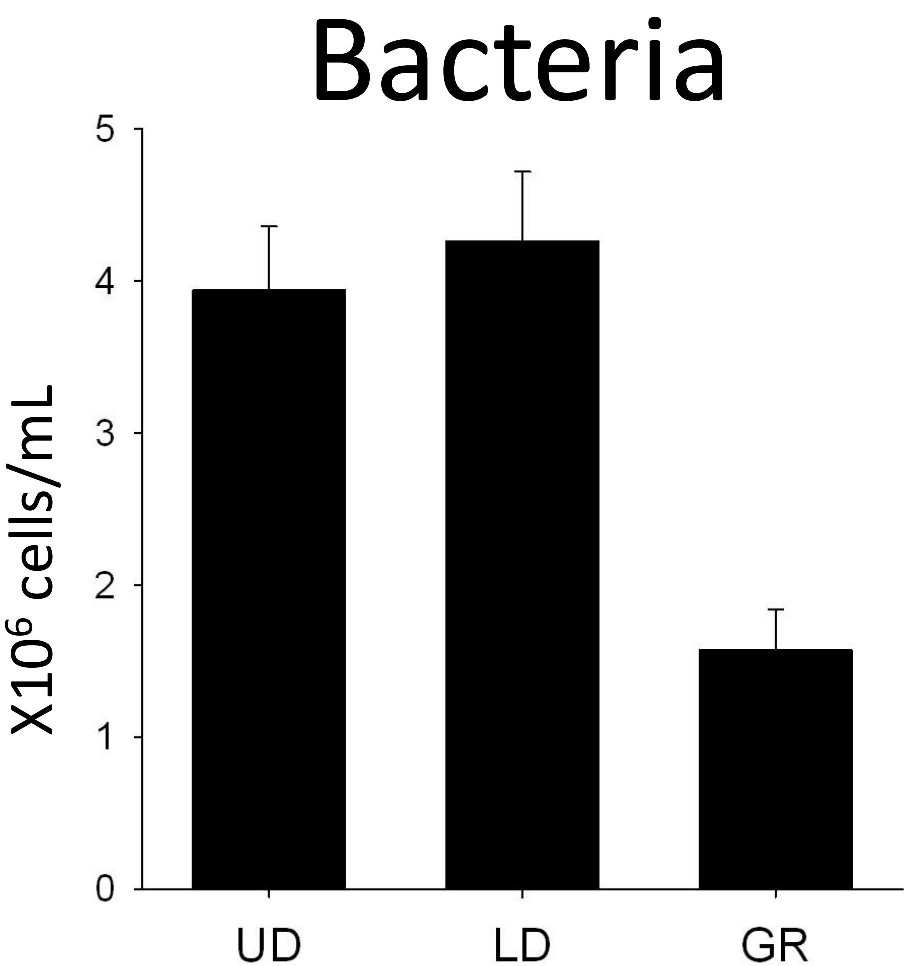
- Physicochemical
  - Temp, DO, salinity
  - Q_9
  - TN, TP, SRP, NH_4^+, NO_3^{2-}
- C Quality and Quantity
  - DOC, OC_L
  - Abs_{440}
  - POM
  - Bacterial C:N:P

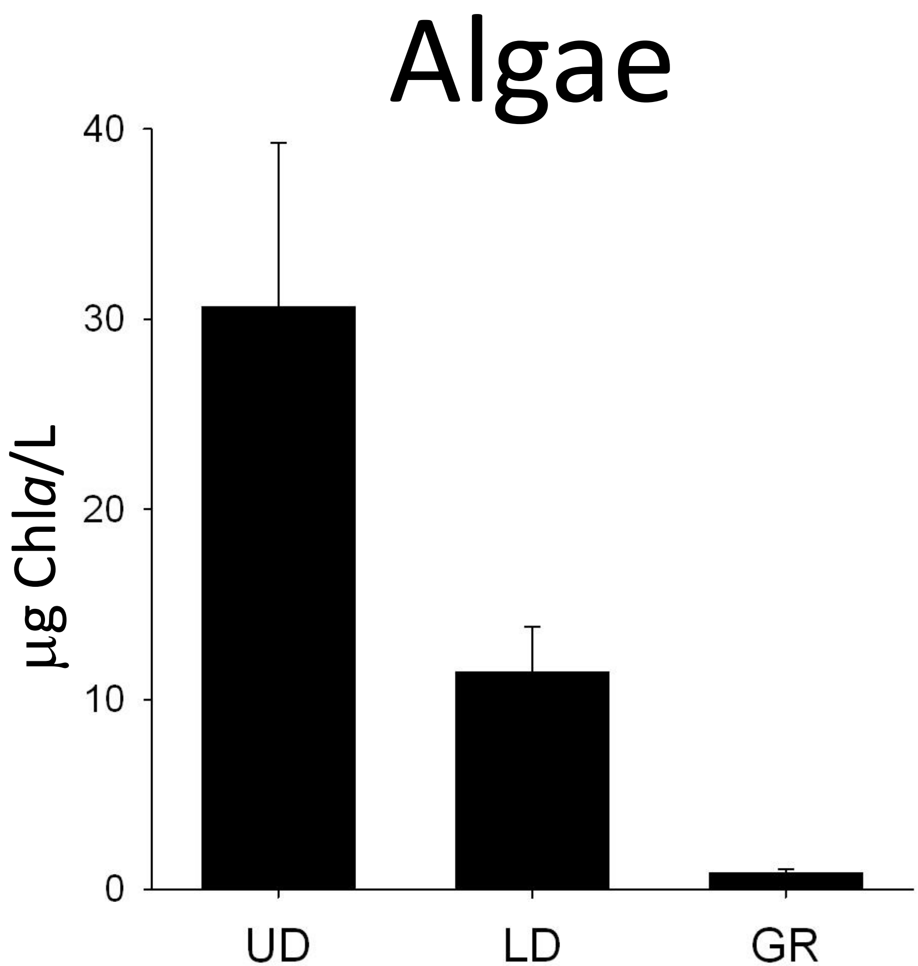
Site Groups



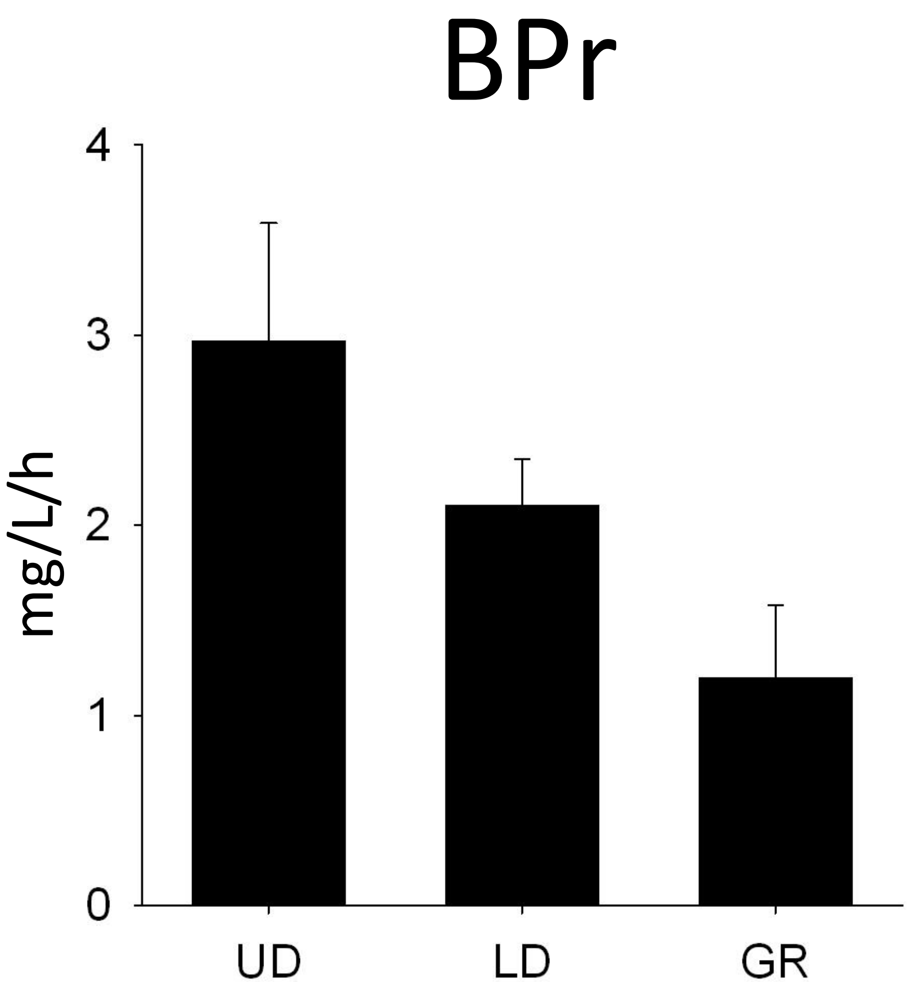
PR1
PR2
PR3
PR4
DR
URG1
URG2
URG3
LRG1
LRG2
LRG3
LRG4
LRG5
LRG7
N
0 75150 300 450
km

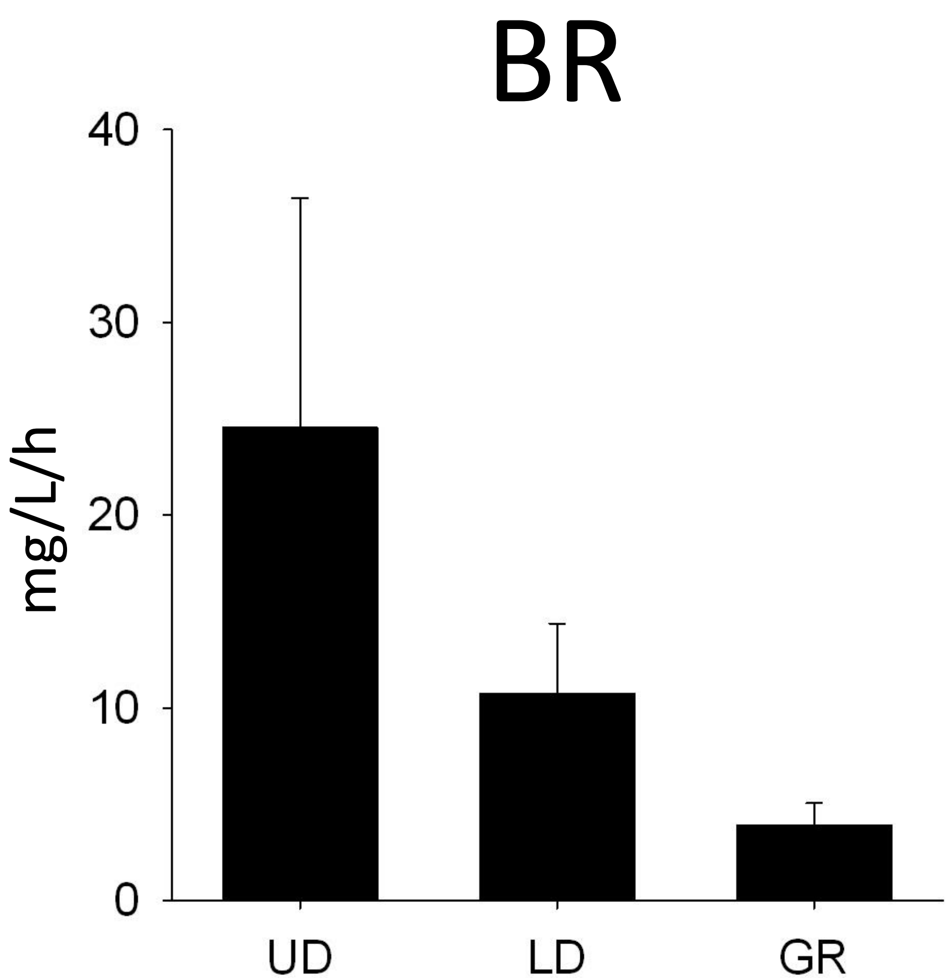
Bacteria Density and Algal Biomass





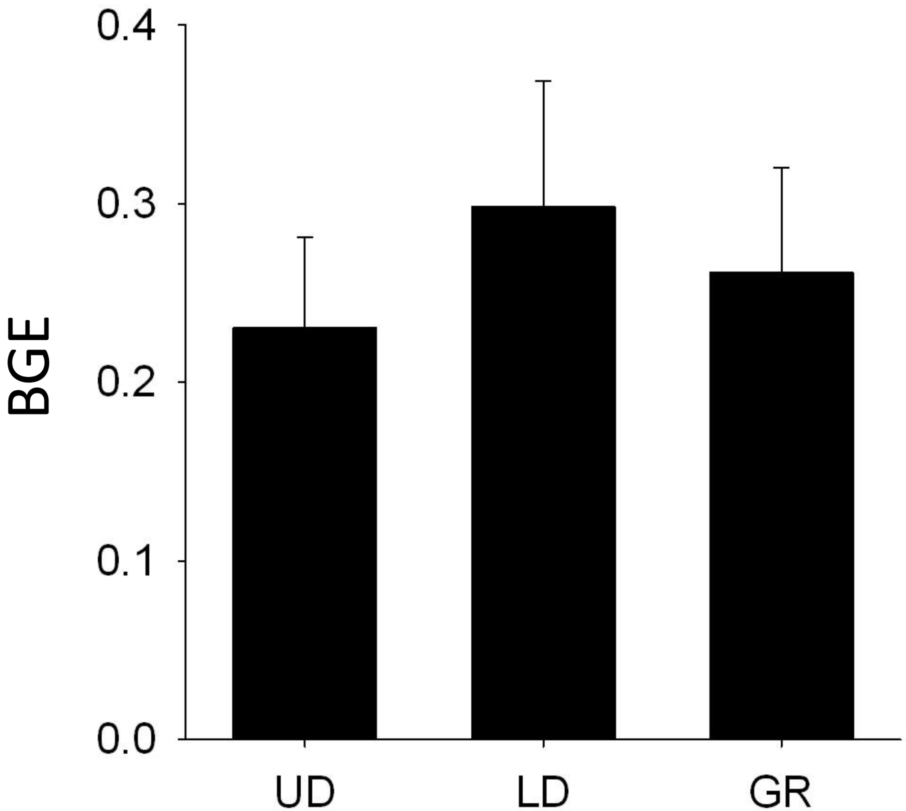
Bacteria Production and Respiration



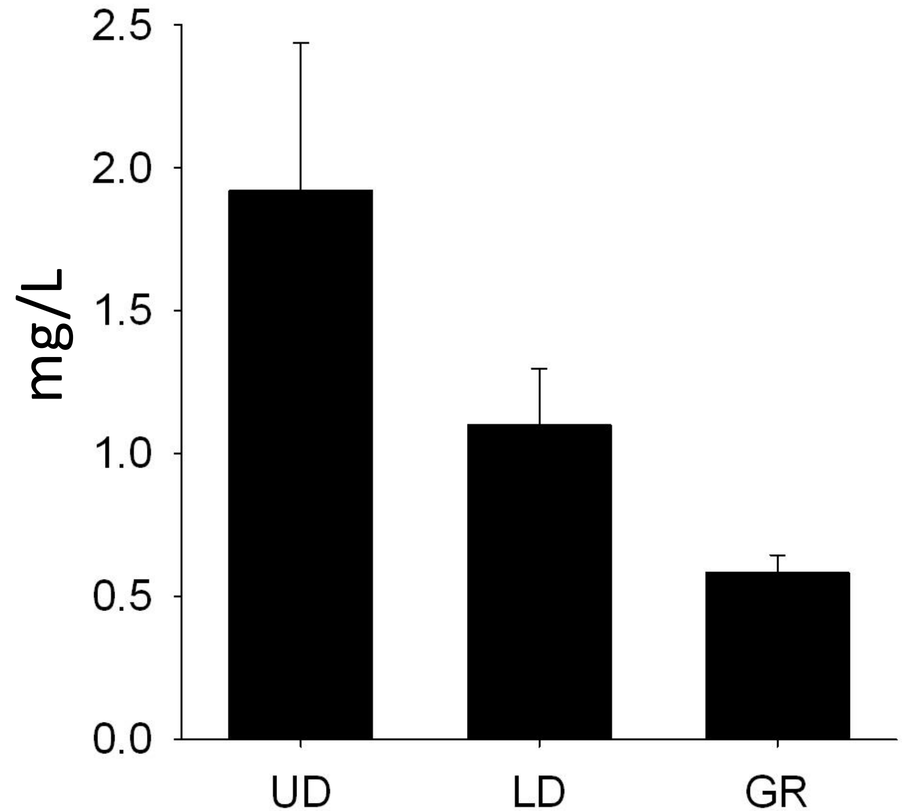


Bacteria Growth Efficiency and OC_L

BGE



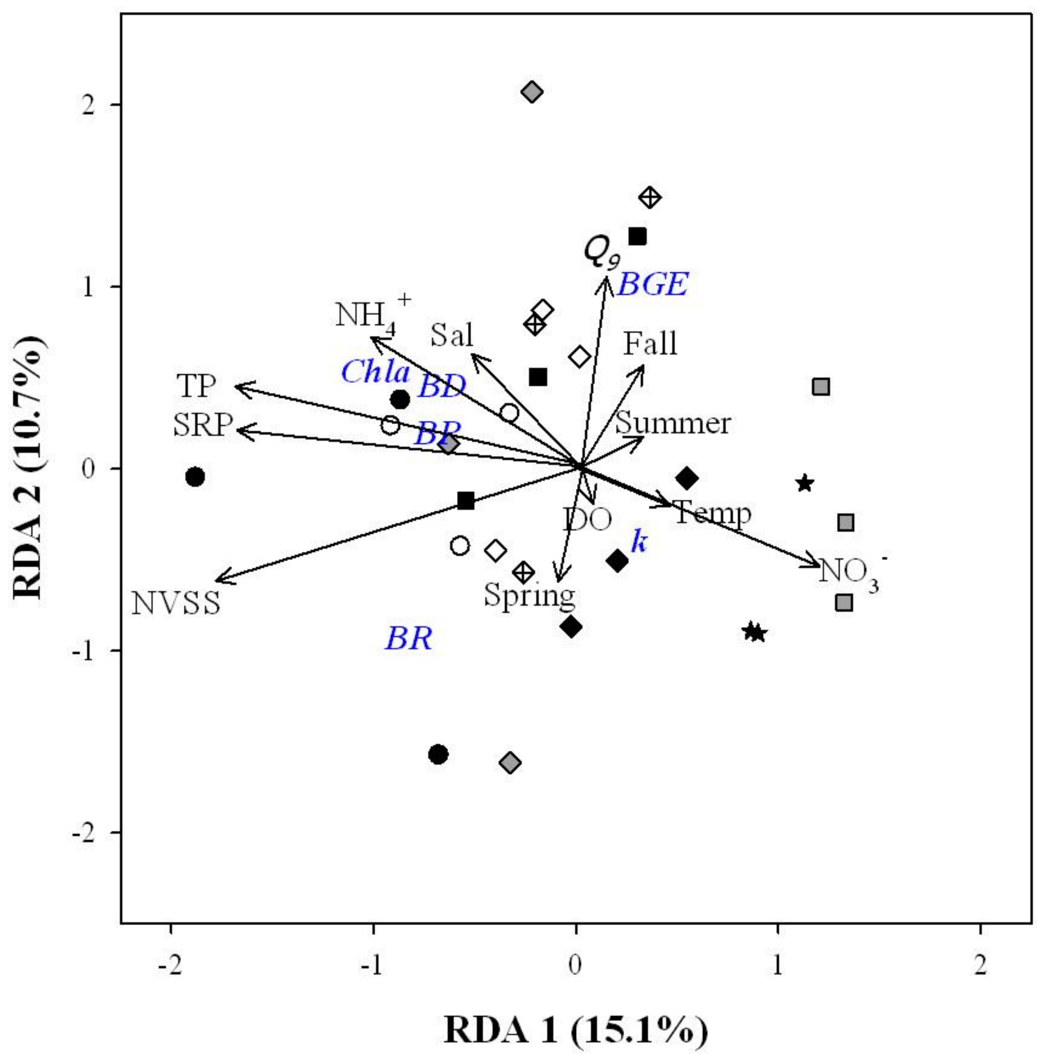
OC_L



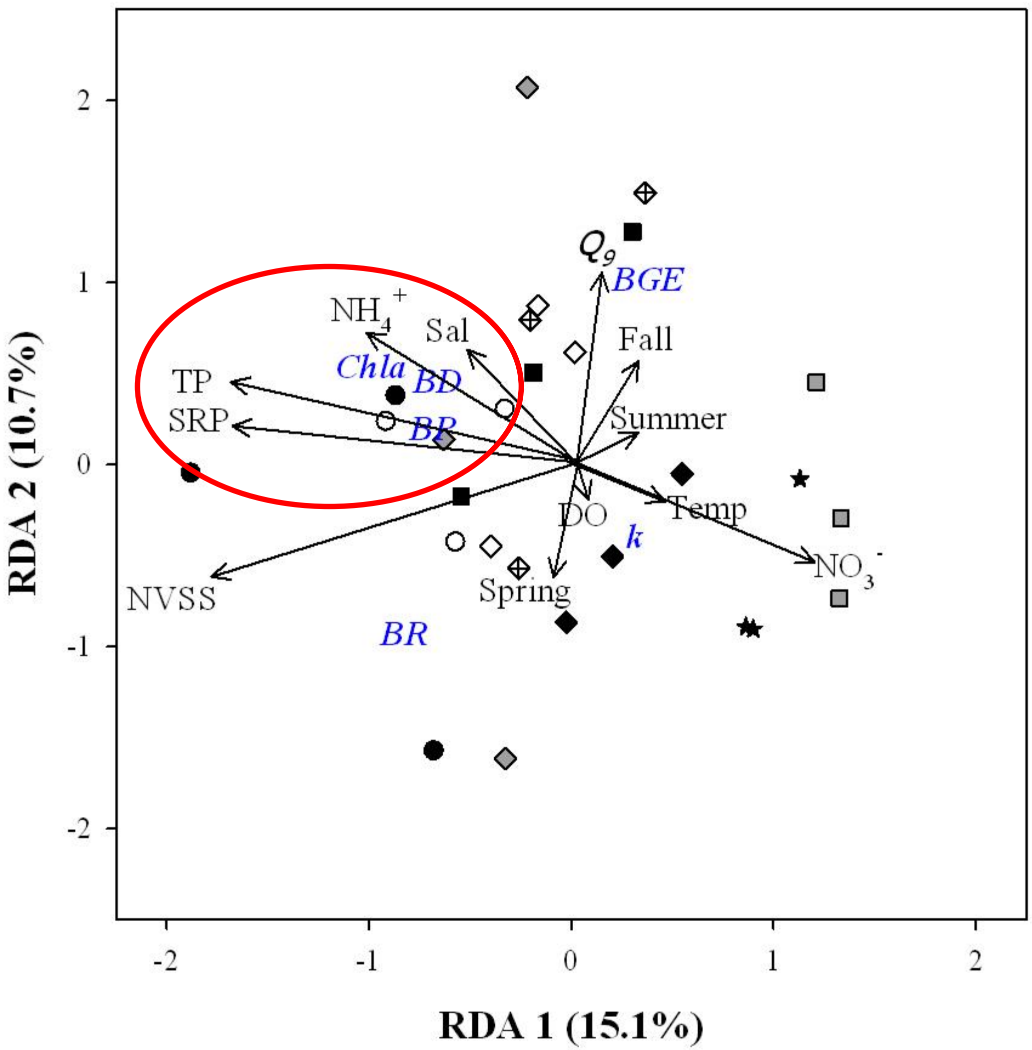
Bacteria Metabolism Responses

- Substantial spatial variation in responses
- Constructed RDA models to explore the influence of these factors on biological responses (BP, BR, BGE, Chl *a*, Bact Dens)
- Two groups of factors
  - Physicochemical factors
  - C quality and quantity
- Variance partitioning

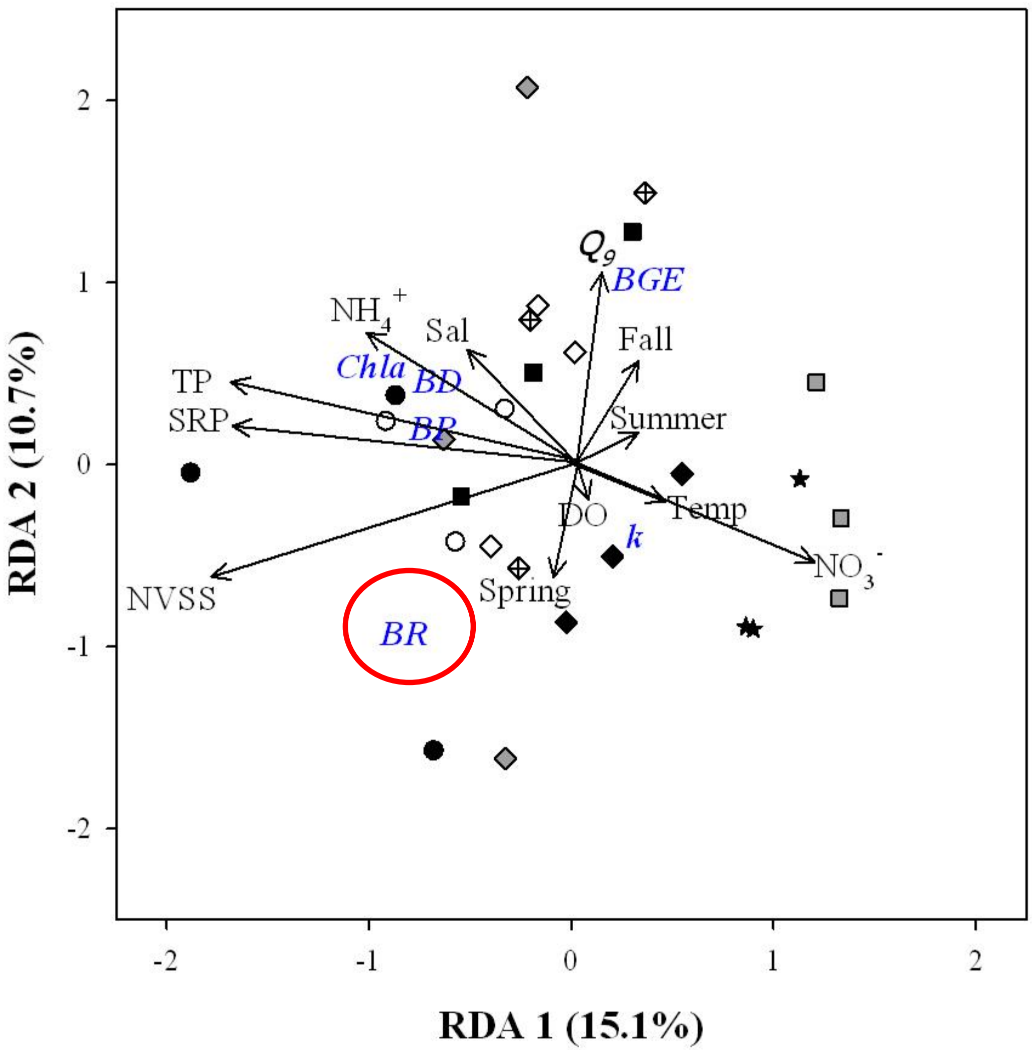
Physicochemical Predictors



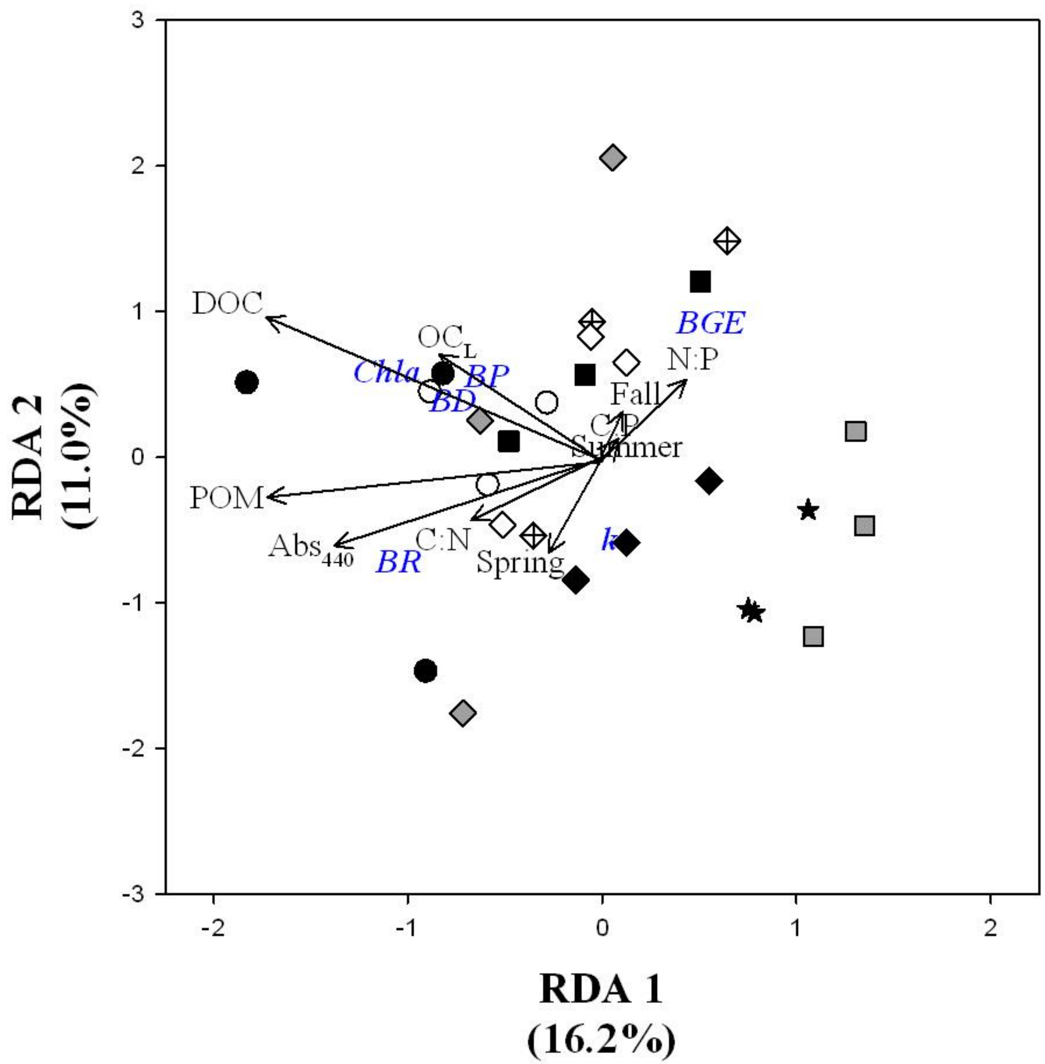
Physicochemical Predictors



Physicochemical Predictors



C Quantity and Quality Predictors



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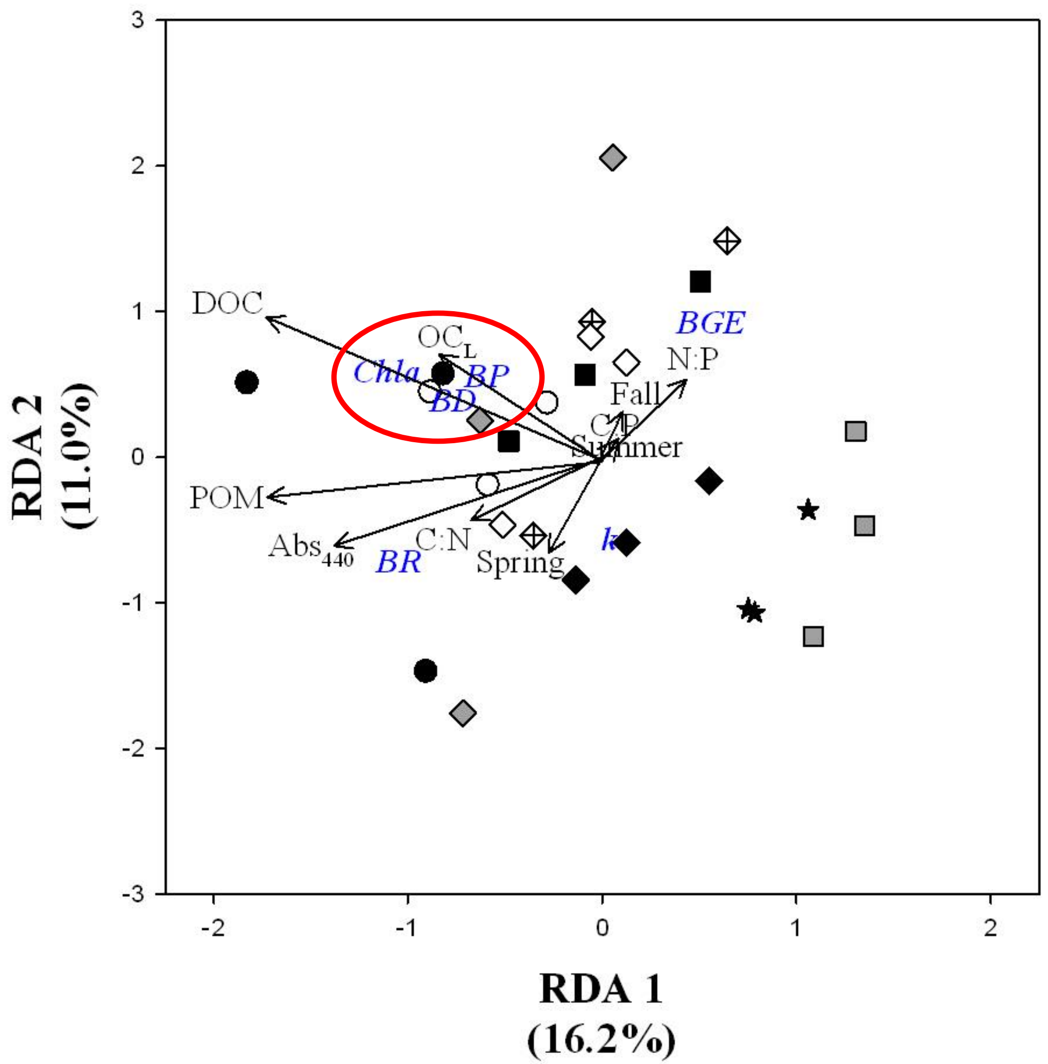

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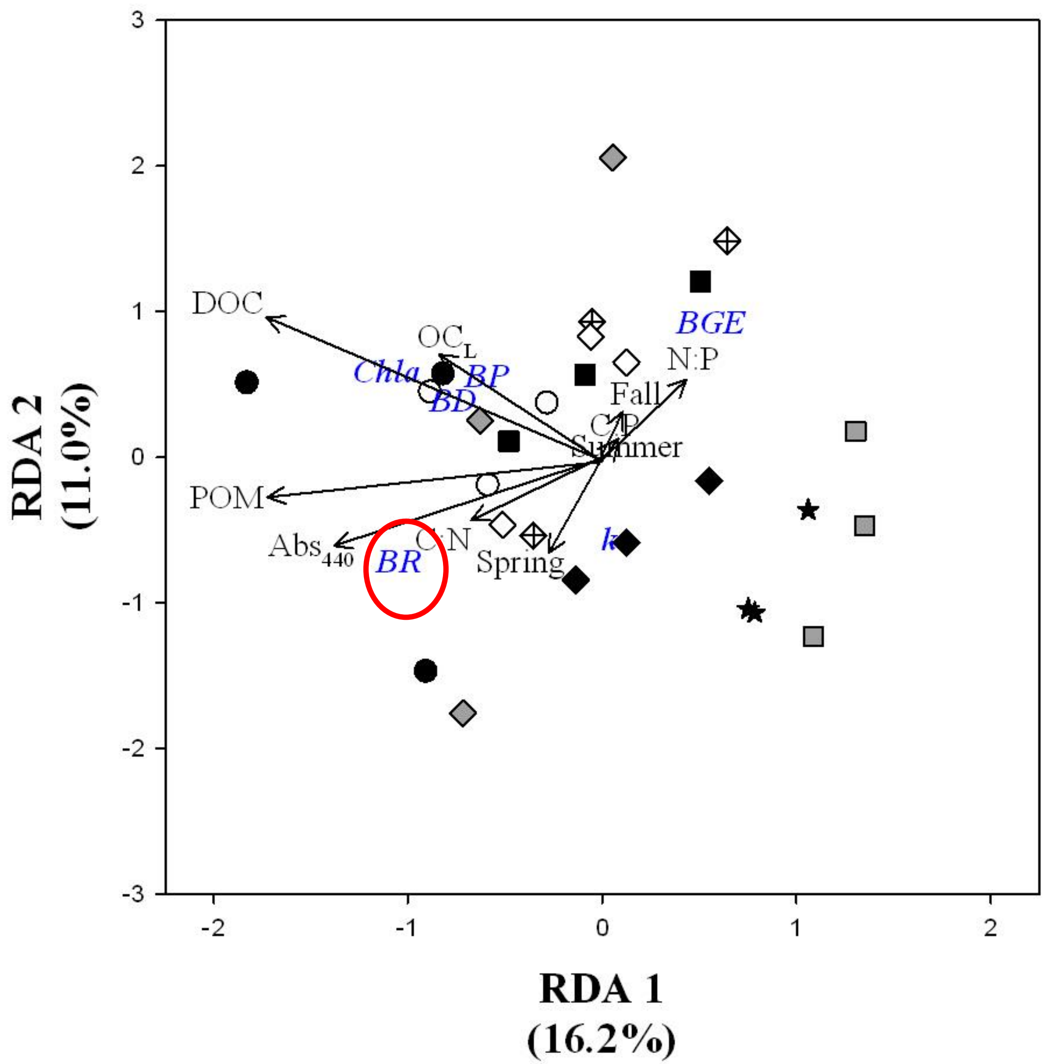

Relative Importance of Predictors?

- Physicochemical predictors
  - 13.9%
- C Quantity and Quality predictors
  - 17.2%
- Approximately equal amount of variation in bacterial responses explained

Conclusions

- Spatial variation in water quality and biological responses
- Substantial variation in bacterial metabolism
  - Productivity and density increased with DOC, OC_L, inorganic nutrients
  - Respiration increases with water color and suspended materials
- Management of bacteria in the basin associated with both inorganic N and P and the amount and quality of DOC

Overall Conclusions

- Rivers are integrated parts of landscapes
- Receive materials, transport materials, and transform materials
- Landscape setting is important
- Biological functions also dependent upon landscape position

Acknowledgements

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USGS
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USDA